DRAFT

Conservation Strategy Short-Listing Analysis Report

Note to Reviewers: *This report provides a narrative overview of the anticipated benefits and drawbacks of each of 22 bundles of potential conservation elements for the BDCP. These bundles were disaggregated from the long list of conservation strategy alternatives (CSAs) developed in February-April. The bundles are evaluated in this report based on the 17 short-listing criteria developed by the Conservation Strategy Workgroup. The purpose of this report is to provide information for the Conservation Strategy Workgroup to use in eliminating and re-aggregating the bundles into a short list of CSAs. Several summary tables accompany this report to provide an easier comparison of bundles.*

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1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE

As part of the Bay-Delta Conservation Plan (BDCP) development process, various approaches to the conservation of covered fish species have been recommended. The purpose of this report is to provide the BDCP Conservation Strategy Workgroup ("Workgroup") with a descriptive analysis of potential elements of the BDCP Conservation Strategy. Based on the analysis presented in this report, the Workgroup will combine sets of conservation elements to create a short list of Conservation Strategy Alternatives (CSAs). The short list of CSAs will be recommended by the Workgroup to the Steering Committee for approval to continued analysis. Once approved by the Steering Committee, the short list of CSAs will be analyzed in detail for conservation benefits and feasibility. It is intended that the short list of CSAs will represent a clearly defined range of differing approaches to achieving the BDCP biological and planning goals and objectives. It is anticipated that a single CSA will be selected and refined by the Steering Committee based on the analysis of the short list of CSAs and that this CSA will be developed in the Conservation Strategy Framework by December of 2007.

As an early step toward creating the Conservation Strategy Framework, the analysis in this report provides information to support a decision process that is anticipated will result in the removal of some conservation elements from further consideration and the combining of compatible conservation elements into several CSAs for further evaluation by the Workgroup.

1.2 CONSERVATION ELEMENT BUNDLES

For the purposes of this report, a "conservation element" (element) is defined as an action or set of interrelated actions with a specific purpose, typically addressing one or a few ecological stressors on covered fish species. Each conservation element may address the conservation of covered species directly such as through mortality reduction or production increase or indirectly such as through habitat enhancement or restoration. Sets of different conservation elements addressing the full range of key stressors on fish make up a "conservation strategy." A conservation strategy is a full program of conservation elements that in total would serve to address all of the goals and objectives of the BDCP

Because of the large number of specific elements that could be included in a conservation strategy for the BDCP, this report analyzes "bundles" of elements (bundles). Each bundle encompasses elements that are related in their physical implementation and overall conservation purpose and that would be logically implemented together. The bundles are grouped into four categories based on the type of actions they include:

- *Water Operations and Conveyance bundles* are water conveyance and export management elements, including some large scale Delta infrastructure construction options (e.g., peripheral aqueduct construction).
- *Entrainment and Predation Mortality Reduction Bundles* include physical modification of pumps and intakes to avoid impacts on covered species, and physical habitat improvements that would help fish avoid predation.
- *Flow-related Habitat Improvement Bundles* include re-operation, modification, or expansion of existing infrastructure in and upstream of the Delta to improve hydrologic and

habitat conditions for covered species of fish, and also physical modification of habitat to improve water flow conditions for covered species of fish.
- *Physical Habitat Restoration Bundles* include physical improvements to enhance and restore habitat in historical habitat areas in the Delta and in downstream and upstream areas.

This report includes 22 bundles of elements for analysis based on short-listing criteria established by the Workgroup. An evaluation of each bundle is contained within each of the major sections of this report.

1.3 EVALUATION CRITERIA

The evaluation of the conservation element bundles is based on application of short-listing criteria developed by the Workgroup. These criteria were developed based on the BDCP Planning Agreement (i.e., the Planning Agreement Planning Goals [section 3] and Preliminary Conservation Objectives [section 6]); draft BDCP Conservation Objectives approved by the Workgroup and BDCP Steering Committee; and previously developed criteria for evaluating approaches to conserving the Delta (Mount *et al*. 2006)[1]. Criteria are classified in four categories: biological, planning, flexibility/durability/sustainability, and other resource impacts.

The following are the 17 criteria that were applied to each of the 22 bundles of elements:

Biological Criteria

1. Relative degree to which the bundle would reduce species mortality attributable to non-natural mortality sources, in order to enhance production (reproduction, growth, survival), abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).
2. Relative degree to which the bundle would provide water quality and flow conditions necessary to enhance production (reproduction, growth, survival) , abundance, and distribution for each of the covered fish species (BDCP Conservation Objective).
3. Relative degree to which the bundle would increase habitat quality, quantity, accessibility, and diversity in order to enhance and sustain production (reproduction, growth, survival), abundance, and distribution; and to improve the resiliency of each of the covered species' populations to environmental change and variable hydrology (BDCP Conservation Objective).
4. Relative degree to which the bundle would increase food quality, quantity, and accessibility (e.g., phytoplankton, zooplankton, macro-invertebrates, forage fish) to enhance production (reproduction, growth, survival) and abundance for each of the covered fish species (BDCP Conservation Objective).
5. Relative degree to which the bundle would reduce the abundance of non-native competitors and predators to increase native species production (reproduction,

[1] Mount, Jeffrey, Robert Twiss, and Richard M. Adams. 2006. *The Role of Science in the Delta Visioning Process: A report of the Delta Science Panel of the CALFED Science Program.* Available online at http://science.calwater.ca.gov/pdf/CSP_delta_vision_process_Twiss_062306.pdf

growth, survival), abundance and distribution for each of the covered fish species (BDCP Conservation Objective).

6. Relative degree to which the bundle improves ecosystem processes in the BDCP planning area to support aquatic and associated habitats (BDCP Conservation Objective).
7. Relative degree to which the bundle can be implemented within a timeframe to meet the near-term needs of each covered fish species (post BDCP authorization).

Planning Criteria

8. Relative degree to which the bundle allows covered activities to be implemented in a way that meets the goals and purposes of those activities.
9. The relative feasibility and practicability of the bundle, including the ability to fund, engineer, and implement.
10. Relative costs (including infrastructure, operations, and management) associated with implementing the bundle.

Flexibility/Durability/Sustainability Criteria

11. Relative degree to which the bundle will be able to withstand the effects of climate change (e.g., sea level rise, changes in runoff), variable hydrology, seismic events, subsidence of Delta islands, and other large-scale changes to the Delta.
12. Relative degree to which the bundle could improve ecosystem processes that support the long term needs of each of the covered species and their habitats with minimal future input of resources.
13. Relative degree to which the bundle can be adapted to address needs of covered fish species over time.
14. Relative degree of reversibility of the bundle once implemented.

Other Resource Impacts Criteria

15. Relative degree to which the bundle avoids impacts on the distribution and abundance of other native species in the BDCP Planning Area.
16. Relative degree to which the bundle avoids impacts on the human environment.
17. Relative degree of risk of the bundle causing impacts on sensitive species and habitats in areas outside of the BDCP Planning Area.

Throughout this report the short-listing criteria (CSL) are referred to by the criteria number (e.g. "SLC 1") given in this list, above.

1.4 EVALUATION PROCESS

Each of the bundles was qualitatively assessed against the criteria. The evaluation was conducted only for species currently identified as covered species in the BDCP Planning Agreement. The criteria were applied using the professional judgment of experts - including information developed in technical sessions of BDCP biologists addressing fish stressors and conservation elements - based on the present understanding of how the Bay-Delta ecosystem operates. The level of certainty regarding expert conclusions for the evaluations of biological criteria is included in the narrative discussion for each bundle.

Key assumptions about how a bundle would be implemented or function that were used to reach conclusions about how that bundle addresses a specific criterion are also included in the narrative. The bundles were compared to each other as to their relative effectiveness and to existing conditions in the Delta under existing operations.

Many but not all bundles are compatible with each other; a compatibility analysis table of the bundles has been prepared to assist the Workgroup in combining the elements into cohesive, logical CSAs.

Application of the criteria is intended to provide an assessment of the relative effectiveness of the bundles of elements in meeting the criteria. The analysis is qualitative only. It is anticipated that a quantitative analysis of CSAs will be undertaken after the short list of CSAs is established by the Workgroup and Steering Committee.

1.5 DOCUMENT PREPARERS

The following individuals assisted with preparation of the evaluation of the conservation element bundles:

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2.0 WATER OPERATIONS AND CONVEYANCE BUNDLES

2.1 BUNDLE #1: REAL-TIME OPERATION OF CVP/SWP PUMPS TO MINIMIZE ENTRAINMENT OF FISH DURING SENSITIVE TIME PERIODS

Bundle 1 includes elements that involve real-time operation of CVP/SWP pumps to minimize entrainment of fish during sensitive time periods:

- 1a. Operate CVP/SWP pumps in real time, based on fish monitoring data, to minimize entrainment of fish during sensitive time periods
- 1b. Reduce reverse flows in Old River and Middle River (net westward flow)

2.1.1 Biological Criteria (#1-#7)

2.1.1.1 Smelt (Delta and Longfin)

Real-time operations use monitoring information to reduce diversion operations during periods of peak salvage abundance. As a result of delays in obtaining monitoring results, reactive time for operational decisions, and the short duration of many real-time operations have contributed to a relatively small incremental reduction in overall mortality as a result of the SWP and CVP operations. Real-time operations typically do not affect salvage mortality at lower levels. For Delta and longfin smelt there are also questions with respect to the particular lifestage that should be targeted for real-time operations, and the ability of real-time operations to affect a population-level response. Real-time operations at the SWP and CVP do not directly affect mortality for Delta or longfin smelt elsewhere within the Delta. The incremental effect of real-time operations on Delta and longfin smelt is considered to be low. Based on current information, it is uncertain that reducing reverse flows in Old and Middle Rivers would substantially reduce entrainment of Delta Smelt (Short-Listing Criteria [SLC]1).

Real-time operations would provide a small short-term modification to hydrology but would not be expected to be of sufficient duration to enhance species production. This action would have very little effect on either water quality or flow conditions that would benefit Delta to longfin smelt (SLC 2).

Real-time operations would not affect the abundance of non-native competitors or predators. other than the potential for a small incremental change as a result of shifting seasonal diversions from one season to another that may incidentally affect a non-native species (SLC 5).

Real-time operations can be implemented within a short (hours or days) time period and therefore offer opportunities to modify SWP and CVP operations to meet near-term needs of each covered species based on its peak abundance at the salvage facilities (SLC 7). Although implementation of real-time operations can be accomplished rapidly the duration of implementation is typically short (days/weeks) and therefore offers little or no long-term benefit to either Delta or longfin smelt.

2.1.1.2 Sturgeon (Green and White)

Regulating the operation of the CVP and SWP pumps according to real-time data-based management decisions would have a minor effect on the reduction of non-natural mortality of sturgeon (SLC 1). The salvage of sturgeon at the pumps of the CVP and SWP is relatively low in part due to the fact that sturgeon are demersal and that they tend to inhabit regions of the Delta closer to their origin, the Sacramento River. The salvage of sturgeon is highest in the summer months and real-time operations could moderately reduce entrainment, but this would likely have only a very small incremental effect on sturgeon population abundance.

Real-time operations of the SWP and CVP pumps would allow for relatively fast implementation time when compared to the other operation bundles and, therefore, could meet the short term needs of sturgeon (SLC 7) though the beneficial effects would likely be minor. Because no structures would have to be built, and the CVP/SWP facilities currently have the capacity to alter pumping, the only foreseeable preparation would be in developing a predictive monitoring plan to detect sturgeon before they reach the salvage facilities and implementing a decision making process for operation reduction criteria.

The effect of this bundle to the sturgeon population is probably low. Based on the available information, the certainty of the assessment of this bundle is high.

2.1.1.3 Salmonids

Real time operation of the CVP and SWP pumps would moderately reduce non-natural mortality of salmonids (SLC 1). For example, if pumping were curtailed while threatened and endangered runs were outmigrating, there is a lower chance of entrainment and of fish becoming lost in the Delta if reverse flows were occurring. This would be more important for salmonids ESUs with lower populations, such as winter-, late fall-, and spring-run Chinook. In this case, the effect on the overall population could be more severe. The biological benefits of real-time operations would depend, in part, on the frequency, magnitude, and duration of export reductions.

The effect of real-time operations on water quality and flow conditions (SLC 2) would likely be low for salmonids. This action may provide better water quality and flow to and in down stream regions of the estuary, which would benefit juveniles waiting to exit into the bay and ocean. Overall, the effect on water quality related to salmonid populations would likely be minimal.

Based on the available information, the certainty of the assessment of this bundle is considered high.

2.1.1.4 Splittail

Regulating the operation of the CVP and SWP pumps according to real-time data-based management decisions would moderately reduce non-natural mortality of splittail (SLC 1). However, splittail are highly fecund and relatively long-lived (7-9 years). As such, they are able to withstand drought years and reproduce in very high numbers during wet water years. The number of splittail salvaged at the CVP/SWP export facilities is strongly correlated with rainfall in a given year (likely due to availability of the floodplain habitat they require in which to spawn). Therefore, few splittail are entrained when their overall population is low, but large numbers are entrained when their populations are high. As a result, entrainment at the export facilities is likely not a large factor in the relative reduction of population abundance in most years. During periods of extended drought during which little or no production occurs and the adult population is reduced, however, a reduction in the entrainment of adults could measurably increase the reproductive potential of the population to recover following the drought period. Real-time operations, although they may moderately reduce entrainment, would likely have only marginal effects on population abundance in most years.

The effect of real-time operations on water quality and flow conditions (SLC 2) is low given the relatively short duration of real-time export reductions and the large volumes of water passing downstream from the Sacramento and San Joaquin rivers and by tidal currents. Water quality and flow conditions downstream of the pumps (e.g., Suisun Bay and Suisun Marsh, where a large proportion of the non-reproductive adult population and juveniles rear) could be improved if pumping was curtailed during low dissolved oxygen (DO) or high temperature conditions and cooler, oxygenated water from upstream were allowed to travel past the pumps towards Suisun Marsh. However, splittail are very tolerant of a wide range of temperature and DO conditions. Also, the effect of this action on reducing temperature and increasing DO would be very small relative to the contribution of the Sacramento River. Therefore, the effect of this action is expected to be relatively small.

Real-time operations of pumps would likely have little or no effect on splittail habitat (SLC 3). Increased access to spawning habitat could result from this action in rare instances. For example, if reverse flows were occurring in Old and Middle rivers due to pumping, splittail, by trying to migrate "upstream" to spawn, may actually move downstream–real-time operations could reduce the occurrence of reverse flows. This outcome is unlikely, however, because splittail movement upstream to spawn generally co-occurs, but is not obligate, with high flows downstream (when reverse flows are not a problem). In addition, there is very little information on the behavior or movement of juvenile or adult splittail in response to hydrodynamic conditions within the Delta.

Real-time operations allow for very fast implementation time relative to the other operation bundles and, therefore, could meet the short-term needs of splittail (SLC 7), although, as stated above, the beneficial effects would likely be minor. Because there are no structures to be built, and the SWP/CVP facilities currently have the capacity to alter pumping, the only foreseeable preparation would be in developing a monitoring program that detects the occurrence of splittail before they reach the export facilities, identifying sensitive biologic and hydrodynamic triggers for actions, and implementing a decision process for operation reduction criteria.

Based on the available information, the certainty of the assessment of this bundle is considered high.

2.1.2 Planning Criteria (#8-#10)

Bundle #1 could be implemented in a variety of ways that could result in a range of operational scenarios, none of which would be expected to affect proposed operation of Mirant's Delta plants. If improved understanding of fish behavior and habitat needs over time leads to more efficient restrictions that protect fish at less water cost, Bundle #1 could lead to modest increases in exports. In that case, this bundle could meet the goals of DWR the SWP contractors who want to maintain or enhance current export levels. On the other hand, if improved understanding of fish needs leads to more restrictive operations, exports could be less than under current conditions. In that case, Bundle #1 would not contribute towards meeting the goals of the CVP and SWP Potentially Regulated Entities (PREs).

Bundle #1 would not involve any new construction or significant additional capital costs, so engineering and funding feasibility is considered high. Monitoring costs, however, may be higher relative to current CVP/SWP operations. The main feasibility issue with Bundle #1 is whether sufficient knowledge currently exists or is likely to exist in the near future to allow more effective real-time operations to occur. Since 2000, export operations have been implemented in a more flexible adaptive management fashion than in the past, with the Environmental Water Account (EWA) being the main tool used to restrict exports to protect fish. It is assumed that scientific knowledge regarding covered species ecology (particularly the Delta smelt) will improve over time and that will lead to improved tools for managing exports. However, it is not certain whether knowledge will improve quickly enough to be useful in reversing declines in fish populations, or whether there are limits to our ability to understand or predict fish behavior that would limit the effectiveness of these tools.

2.1.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

The effectiveness of Bundle #1 could be affected by climate change in future years if shifts in the hydrologic cycle reduce the flexibility of reservoir operations to accommodate exports. Implementation of this bundle also relies on maintenance of the existing conveyance system, which could be adversely affected by seismic events and island subsidence.

This bundle provides minimal support for ecosystem processes relative to Bundles 3-7 because it will require ongoing manipulation of Delta in-flows and through Delta channel flows to meet export needs. To the extent that entrainment is a stressor for each of the covered species, however, real-time operation of pumps to minimize entrainment is expected to be highly adaptable at both short (daily to monthly) and longer time scales (seasonally and supraannually). Because this bundle does not involve the construction of any substantial new facilities or the expenditure of large amounts of money, it is likely the most reversible of the water operations and conveyance bundles.

2.1.4 Other Resource Impacts Criteria (#15-#17)

Real-time operation of the CVP/SWP pumps is the least likely of the operations bundles to measurably affect other native species, either inside or outside the planning area. Because it does not rely on new construction and energy consumption and air quality would not be affected by the actions proposed, it would also have the fewest impacts on the human environment.

2.2 BUNDLE #2: REDUCED WATER DEMAND AND DELTA DIVERSIONS

Bundle 2 includes elements that involve reducing water demands and Delta diversions to reduce mortality of and benefit ecosystem processes that support covered fish species:

- 2a. Reduced water demand and diversions from the Delta
- 2b. Reduce reverse flows in Old River and Middle River (net westward flow)

2.2.1 Biological Criteria (#1-#7)

2.2.1.1 Smelt (Delta and longfin)

The relative degree to which reduced water demand and Delta diversions would reduce mortality for Delta and longfin smelt varies as a function of the magnitude of the reduction in diversions, geographic location where conversion reductions would occur relative to the geographic distribution of the species, and the seasonal time period when diversion reductions would occur. As a general "rule of thumb" it is typically assumed that diversion losses at any location within the Delta will be roughly proportional to the volume of water diverted (SLC 1).

Changes in water quality, hydrodynamics, and food availability and quality would vary based upon the location, seasonal timing, and magnitude of diversion reduction (SLC 2 and 4). Diversion reductions would affect local hydrodynamics that would have a potential positive benefit on habitat conditions for Delta smelt and longfin smelt.

Reduced diversions would be expected to contribute to a reduction in the vulnerability of non-native species to entrainment losses and therefore would not reduce, but rather would increase, the potential abundance of non-native species (SLC 5).

Changes in hydrodynamics and associated water quality within the Delta as a result of reduced diversions would contribute to a small incremental improvement in ecosystem processes, with the magnitude of potential benefit being roughly proportional to the diversion reduction (SLC 6).

The rate of implementing diversion reductions would depend on the rate of reducing demands through conservation, development of alternative water supply sources, or other actions. These changes would be expected to occur over the near-term (years) and long-term (decades) planning horizon.

2.2.1.2 Sturgeon (Green and White)

Reducing Delta water demand and reducing the reverse flows on Old and Middle rivers would have an unknown effect on the non-natural mortality of sturgeon (SLC 1). Juvenile sturgeon are most sensitive to entrainment during the summer and early fall. After spawning upstream of the Delta, juvenile sturgeon spend 1-4 years rearing in the Delta. Other than CVP/SWP salvage data, it is not known what impact Delta diversions in general are having on the non-natural mortality of sturgeon. As a result, it is difficult to determine the benefit, if any, of reducing diversions and reverse flows of Old and Middle rivers.

Reducing Delta water demand in addition to reducing the reverse flows on Old and Middle rivers would allow for relatively fast implementation time when compared to the other operation bundles and, therefore, could meet the short term needs of sturgeon (SLC 7) though the beneficial effects are unknown. Because no structures would have to be built, the reductions in diversions and the reduction of reverse flows on Old and Middle rivers could be implemented in a relatively fast timeframe.

The effect of this bundle to the sturgeon population is unknown but probably low. Based on the available information, the certainty of this assessment is also low.

2.2.1.3 Salmonids

A reduction in water demand and Delta diversions should moderately reduce salmonid mortality (SLC 1) by reducing entrainment. This effect will be more pronounced on less common ESUs. This benefit would vary depending on the magnitude and seasonal timing when diversion operations would be reduced.

A reduction in water demand and Delta diversions should have a limited positive effect on water quality and flow conditions (SLC 2), but this effect is largely dependent on the amount of the reduction and locations of diversions. The positive effect is also limited by the high tolerance of salmonid smolts to a wide range in salinity. Relative to other water operations and conveyance bundles, the effect will likely not be as high as bundles that allow for variable salinity and increased through-Delta conveyance.

Depending on how a eduction in water demand and Delta diversions will affect upstream storage releases and dams, this bundle could result in a major improvement to salmonid habitat (SLC 3). For example, if reverse flows were occurring in Old and Middle rivers due to pumping, salmonids (particularly those retuning to the San Joaquin River), by trying to migrate "upstream" to spawn, may become confused and actually move downstream–reduced water demands and Delta diversions would reduce the occurrence of reverse flows.

It is not well known how long a reduction in demand and Delta diversions might take in terms of it being within a time frame to meet the near-term needs of salmonids (SLC 7). However, it is likely that the implementation would take longer than Bundles 1 and 3, but not as long as those requiring construction (Bundles 3-8).

Based on the available information, the certainty of the assessment of this bundle is considered high.

2.2.1.4 Splittail

A reduction in water demand and Delta diversions would likely reduce splittail mortality (SLC 1) by reducing entrainment of splittail. However, as stated in 2.1.1.4, the number of splittail removed by diversions is likely dependent on the abundance of splittail at the time. The abundance of splittail is likely a result of the type of water year, thus having a relatively small effect on the population during most water years. Only when there is a prolonged drought with little or no production and the adult population is much reduced could entrainment have a marked effect on the population. Therefore, the effect of reduced demand and diversions will be moderate relative to other water operation and conveyance bundles.

A reduction in water demand and Delta diversions should have a limited positive effect on water quality and flow conditions (SLC 2), but this effect is largely dependent on the amount of the reduction and locations of diversions. The positive effect is also limited by the high tolerance of splittail to a wide range in DO, salinity, and temperature. Relative to other water operation and conveyance bundles, the effect will likely not be as high as bundles that allow for variable salinity and increased through-Delta conveyance.

Unless a reduction in water demand and Delta diversions will affect upstream storage releases, this bundle would likely have little or no effect on splittail habitat (SLC 3). Increased access to spawning habitat could result from this action in rare instances. For example, if reverse flows were occurring in Old and Middle rivers due to pumping, splittail, by trying to migrate "upstream" to spawn, may actually move downstream–reduced water demands and Delta diversions would reduce the occurrence of reverse flows. Also, if there is a barrier to passage upstream due to extremely low water levels (river going dry, or a physical impediment blocking passage), splittail may not be able to access floodplain spawning habitat. These scenarios are highly unlikely, however, because splittail movement upstream to spawn generally co-occurs, but is not obligate, with high flows downstream (when reverse flows and low water levels are not a problem).

It is not well known how long a reduction in demand and Delta diversions might take in terms of it being within a time frame to meet the near-term needs of splittail (SLC 7). However, it is likely that the implementation would take longer than Bundles 1 and 3, but not as long as those requiring construction (Bundles 4-8). Regardless, it is not likely that rapid implementation of this bundle would have a major impact on splittail because the bundle itself will have only a moderate effect on splittail populations.

Based on the available information, the certainty of the assessment of this bundle is considered high.

2.2.2 Planning Criteria (#8-#10)

Reducing water demand and Delta exports would be contrary to the stated goals of the SWP and CVP PREs to continue exports at current or even increased levels. Therefore, this bundle would not meet Criteria #8. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

Reducing exports, however, can be accomplished with existing facilities and therefore does not entail any significant additional capital costs. Consequently, funding feasibility is considered high. The specific actions to be taken to reduce demand for Delta water are not known at this time. Some actions could involve construction of water recycling or desalination plants. Other methods to encourage or provide incentives for business and consumer-based water conservation (e.g. installation of more water efficient plumping, appliances, and equipment; changes in landscaping and irrigation practices) would not involve construction of large new facilities. These methods have been widely adopted in water-short areas and present no significant engineering challenges. In areas where many water conservation actions have already been widely implemented, implementing Bundle #2 may face challenges related to acceptance by consumers and businesses and the cost-effectiveness of implementing further measures. Another feasibility challenge lies in whether conservation efforts could have a sufficient effect on demand to allow reductions in future export levels.

2.2.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Bundle #2 would reduce reliance on Delta exports and therefore would reduce overall risk related to levee breach events, however the remaining exports would still be subject to disruption due to levee breaching that could be associated with seismic events, sea level rise, or other causes.

This bundle provides minimal support for ecosystem processes relative to Bundles 3-7 because it will require ongoing manipulation of Delta in-flows and through Delta channel flows to meet export needs. Reduced water diversions would likely have low adaptability at a short time scale, and moderate adaptability at a longer time scale. Development of alternate water supplies and demand reduction actions (e.g., behavior change, regulation, incentive programs, pricing change) are long-term actions and could be politically constrained. Unpredictability in future levels and timing of water flows reduce certainty of this bundle's adaptability.

Water demand reduction actions at the scale of the individual household would be completely reversible, though there would likely not be a reason to reverse them. On the other hand, the implementation of water conservation equipment for businesses would be somewhat less reversible, and the development of alternative water supply and conservation facilities (e.g., large water reclamation or desalination plants) would be even more difficult to reverse because of the higher capital costs involved.

2.2.4 Other Resource Impacts Criteria (#15-#17)

Reduced water demand and diversions are not expected to significantly affect other native species, either inside or outside the planning area. Because Bundle #2 does not rely on new construction and energy consumption and air quality would not be affected by the actions proposed, it would have the few impacts on the human environment.

2.3 BUNDLE #3: EXPORT WATER OPPORTUNISTICALLY

Bundle 3 includes elements that involve operation of CVP and SWP facilities to export water opportunistically from the Delta to reduce mortality of and benefit ecosystem processes that support covered fish species:

- 3a. Increase CVP/SWP pumping capacity to take advantage of high flow episodes with pumping limited at other times when covered species are least vulnerable to entrainment and no pumping at times they are most vulnerable to entrainment
- 3b. Provide flows that improve flow-related habitat conditions that mimic historical hydrological patterns (e.g. fluctuating salinity, east-west flow)
- 3c. Increased conveyance capacity south of Delta and additional south-of-Delta storage facilities and infrastructure to opportunistically store high flows, including concurrent improvements to louver facilities to minimize fish mortality.

2.3.1 Biological Criteria (#1-#7)

2.3.1.1 Smelt (Delta and longfin)

Opportunistic exports would generally rely on increasing the rate of diversions at the SWP and CVP during those seasonal periods when water supplies are available and the vulnerability of Delta or longfin smelt is reduced either as a result of the relative magnitude of Delta inflows relative to exports and/or opportunistically exporting during seasonal periods when Delta and longfin smelt not present in the southern Delta. Opportunistic exports during the winter and early spring may be timed in such a manner as to avoid or reduce the vulnerability of adult Delta and longfin smelt, however because of the timing of spawning of the two species planktonic larvae in early juvenile lifestages would be expected to continue to be vulnerable to entrainment losses during the late winter or spring. Opportunistic exports during the summer months could be used to reduce or avoid entrainment losses of both Delta and longfin smelt as a result of their seasonal geographic distribution within the Delta however, the availability of water supplies during the summer months and water quality effects may reduce opportunities for opportunistic export operations. As a result of these constraints the relative contribution of opportunistic export operations on reducing the vulnerability of Delta and longfin smelt to export effects of the SWP and CVP is considered to be relatively small. The potential magnitude of biological benefits for opportunistic export operations during the winter and early spring for Delta and longfin smelt would also vary based upon hydrologic conditions (e.g., the magnitude of Delta outflows and the associated geographic distribution of smelt) relative to the volumes of water being exported. Under very high Delta outflow conditions opportunistic export operations would be expected to have a greater biological benefit for smelt when compared to hydrologic periods when Delta outflow is substantially reduced (SLC 1).

Opportunistic export operations would provide some incremental benefit to hydrologic conditions within Delta. The potential benefit to hydrologic conditions would be based on the relative magnitude of Delta inflow and Delta outflow relative to export rates. The incremental benefit of opportunistic exports would vary depending on the resulting changes in export operations during both the period of increased exports as well as during periods throughout the rest of the year when export operations are reduced. The actual magnitude of biological benefits would also vary depending on the maximum rate of opportunistic exports and the duration that opportunities for increased exports occur within the Delta based on the magnitude and frequency of seasonal hydrologic opportunities (SLC 2).

Opportunistic export operations have the potential to contribute a small incremental benefit to increased food availability as a result of reducing export operations, and the associated export of the supplies and nutrients, during the year. The actual biological benefit would vary depending on seasonal patterns and the magnitude of export operations relative to baseline conditions (SLC 4).

Opportunistic export operations that would benefit Delta and longfin smelt would also be expected to generally benefit non-native species thereby contributing to a potential increase, rather than a decrease, in the abundance of non-native species (SLC 5).

Opportunistic export operations have the potential to contribute to a small incremental improvement in ecological processes, primarily those associated with changes in Delta hydrodynamics. These changes would be expected to be relatively small (SLC 6).

Opportunistic export operations can be implemented immediately within the constraints imposed by existing export facility capacity. Implementing an opportunistic export operation that requires expansion of existing facilities (e.g., pumping plant capacity, conveyance capacity, fish protection facilities, etc.) would likely require a decade or longer to implement (SLC 7).

2.3.1.2 Sturgeon (green and white)

Increasing CVP/SWP pumping capacity to take advantage of high flow periods and the avoidance of pumping during periods when sturgeon are vulnerable to entrainment would reduce non-natural mortality but the population level effect would likely be low (SLC 1). Increased inflow velocities during operations at CCF have the potential to increase the number of fish entrained. However, avoidance of pumping during the summer when sturgeon are more vulnerable may have an offsetting effect. The population level effect of this element on non-natural mortality would be low.

Providing flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve spawning area quality by cleaning bed material (SLC 2). Reestablishing natural pulse patterns that would have occurred following storm events would be beneficial. This element would have a low to moderate population level effect on sturgeon.

Providing flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve access to spawning areas (SLC3). Flow pulses also act to attract sturgeon to spawning tributaries and aid in egg survival and juvenile transport downstream. As a result, this element would likely have a moderate population level impact on sturgeon.

Altering flows to resemble historic hydrologic conditions would likely reduce non-native sturgeon predators (SLC 5). Non-native species currently residing in the Delta are less likely to tolerate fluctuating salinity conditions when compared with native species, which evolved in a fluctuating salinity environment. Allowing parts of the Delta to experience salinity fluctuations that occurred prior to the construction of the SWP and CVP would have a low to moderate effect on sturgeon population abundance through the reduction of non-native predators since sturgeon are not thought to be highly vulnerable to predation mortality by most non-native fish species.

Increasing CVP/SWP pumping capacity and the construction of south of the Delta storage facilities would require a relatively long time frame when compared to other bundles (SLC 7). Altering flows to mimic historical conditions with fluctuating salinity and pulse flows would provide a moderate benefit to sturgeon and could be implemented in the short-term.

Cumulatively, the effect of this bundle on the sturgeon population is expected to be low to moderate. Based on the available information, the certainty of the assessment of this bundle is moderate to high.

2.3.1.3 Salmonids

Opportunistic exports should moderately reduce mortality of salmonids due to entrainment for reasons discussed in 2.1.1.3 (SLC 1). Improving flow-related habitat conditions may reduce the abundance of non-native predators, which may not be able to tolerate these conditions as well as natives. Thus, mortality from non-native predation would decrease. This bundle may reduce mortality more than Bundles 1 and 2, but would likely not reduce mortality as great as an isolated facility could (Bundles 5 and 7).

If we assume that providing flows that mimic historical hydrological conditions will involve re-operation of upstream storage facilities, this bundle could greatly improve water quality. This bundle would provide highly improved flow conditions for salmonids (SLC 2) by allowing Delta hydrologic conditions to fluctuate in a more historical pattern, in which salmonids evolved. This action would likely provide large benefit to salmonid populations because water quality (DO, temperature) is important to salmonid success. The relative benefits of modified flows would be expected to benefit some salmonid populations (e.g., fall-run) more than others (spring-run and winter-run Chinook) as a result of the interacting effects between seasonal flows and requirements for cold water for spawning.

Opportunistic exports could moderately improve juvenile habitat quantity for salmonids (SLC 3). First, suitable freshwater juvenile rearing habitat and migration corridors could become available by improving hydrologicl conditions. Both freshwater rearing habitat and migration corridors have high conservation value to juvenile salmonids.

Opportunistic exports could likely greatly increase food quality, quantity, and accessibility for salmonids (SLC 3). Salmonids could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality. Further, if floodplains were allowed to flood more naturally, they could provide high levels of productivity into the Delta system. More food will likely translate into higher survival rates of juveniles as they outmigrate and enter the ocean. Therefore, opportunistic exports could have large impacts on overall salmonid populations.

Opportunistic exports could have moderate impacts on reducing abundances of non-native competitors and predators of salmonids (SLC 5) because it may provide physical conditions not be amenable to non-native species. In contrast, opportunistic export operations may result in a reduction in entrainment mortality at the SWP and CVP export facilities and thereby contribute to an increase in the abundance of non-native fish species. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the Delta planning area are generally resilient to wide variety of environmental conditions. Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions.

Opportunistic exports should improve ecosystem processes related to salmonids (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Salmonids could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

Opportunistic exports will require an intermediate level of infrastructure construction (conveyance and storage facilities south of the Delta; SLC 7). Therefore, implementation of this bundle would take longer than Bundles 1-3, but likely not as long as Bundles 3-8.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.3.1.4 Splittail

Opportunistic exports should moderately reduce mortality of splittail due to entrainment for reasons discussed in 2.1.1.4 (SLC 1). Increasing exports during periods of high flows coincides with periods of greater geographic dispersion of juvenile splittail within the rivers and downstream within Suisun Bay and Marsh where their vulnerability to export losses is reduced. Improving flow-related habitat conditions may reduce the abundance of non-native predators, which may not be able to tolerate these conditions as well as natives. Thus, mortality from non-native predation would decrease. This bundle may reduce mortality more than Bundles #1 and 2, but would likely not reduce mortality as great as an isolated facility could (Bundles #5 and 7).

If providing flows that mimic historical hydrological conditions will involve re-operation of upstream storage facilities, this bundle would likely greatly improve water quality. However, these improvements would likely have small effects on overall splittail abundance, distribution, and production because splittail are highly tolerant of a wide range of environmental variables. This bundle would likely provide highly improved flow conditions for splittail (SLC 2) by allowing Delta hydrologic conditions to fluctuate in a more historical pattern, in which splittail evolved. This type of hydrologic cycle would allow floodplains and riparian zones to flood naturally. Floodplains and flooded riparian zones are highly favorable spawning and juvenile rearing habitat for splittail.

Opportunistic exports should increase habitat quantity, quality, and accessibility for splittail (SLC 3) in two ways. First, spawning habitat should become available by fluctuating hydrology, as discussed above. It was generally agreed upon in BDCP Technical Meetings that the reduction in quantity of and accessibility to suitable spawning habitat is one of the top stressors that exist for splittail, particularly the duration of flooding needed for successful spawning and rearing. Second, although splittail can tolerate wide ranges in DO, temperature, and salinity, adults are most abundant in shallow, tidally influenced, brackish sloughs, such as Suisun Marsh and margins of the lower Sacramento River. Fluctuating salinity in the Delta as a result of this bundle will likely create this type of habitat upstream not currently present under existing conditions. However, limited adult splittail habitat was not been identified as a major stressor in BDCP Technical Meetings.

Opportunistic exports would likely increase food quality, quantity, and accessibility for splittail (SLC 4). Splittail could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality and an increase in access to prey on floodplains (reproductive splittail often consume earthworms and other terrestrial organisms in floodplains). In addition, floodplains are highly productive and, if flooded, they could provide high levels of productivity into the Delta system. More food allows for greater growth and larger and healthier fish. Therefore, this bundle would likely allow for large positive impacts on the splittail population.

Opportunistic exports could have moderate impacts on reducing abundances of non-native competitors and predators of splittail (SLC 5) because it may provide conditions not be amenable to non-native species. In contrast, opportunistic exports may reduce the vulnerability of non-native fish species to losses at the SWP and CVP export facilities thereby resulting in an increase in abundance. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the Delta planning area are generally resilient to a wide variety of environmental conditions. Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions. This is the nature of invasive species.

Opportunistic exports should improve ecosystem processes related to splittail (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

Opportunistic exports would likely require an intermediate level of infrastructure construction (conveyance and storage facilities south of the Delta; SLC 7). Therefore, implementation of this bundle would take longer than Bundles 1-3, but likely not as long as Bundles 4-8.

Based on the available information, the certainty of the assessment of this bundle is considered moderate, other than assessment of SLC 5.

2.3.2 Planning criteria (#8-#10)

This bundle has the potential to meet the goals of the SWP and CVP PREs. The period when pumping is allowed will need to be compressed into periods with high flows. In order to maintain or increase the annual volume of water exported, and to account for the potentially long periods between high flow events, much greater amounts will need to be exported during this short period when exports are allowed. Therefore, the capacity of the export facilities, south-of-Delta conveyance facilities, and south-of-Delta storage capacity would need to be greatly increased. An important unknown is whether the current and future hydrology would allow for sufficient exports during the compressed period to allow the CVP and SWP to maintain or increase total annual exports. Therefore, it cannot be determined at this time whether this bundle would meet the goals of the CVP and SWP PREs. If sufficiently large amounts of water could not be exported and stored to meet CVP/SWP demands during the limited time available each year, then this bundle would not meet the planning goals of the CVP/SWP PREs. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

Without specific information about how this bundle would be implemented (how much pumping capacity would need to be added, when pumping would occur, what improvements to conveyance would be needed how much additional storage is needed, whether it would be above ground or below ground, and where the new storage would be located), the feasibility of this bundle cannot be determined. It is not expected that any new technology would be involved in the construction of these facilities, but there may well be engineering feasibility constraints related to their construction and operation in specific locations. Of particular note would be the need to screen the intakes to CCF in order to pump the full capacity of the Banks Pumping Plant (10,300 cfs.). These would be extremely large and challenging screens to construct. Until detailed engineering studies are conducted, it cannot be determined whether this bundle would be feasible, or even possible. However, Because of the uncertainties associated with the expansion of south-of-Delta storage and conveyance facilities, this feasibility of this bundle is likely less than that of Bundles #1 and 2, and roughly equivalent to Bundles #4-7.

This action would increase CVP/SWP pumping capacity above the current maximum permitted level of 6,680 cfs. Increasing the maximum permitted diversion rate to 8,500 cfs would require a range of physical and operational improvements in the south Delta. These actions are embodied in the South Delta Improvement Program (SDIP). Current cost estimates for SDIP are $110.5 million for construction and environmental mitigation, and approximately $1 million per year for operations.[2] Construction and environmental mitigation costs are broken down as follows: permanent operable gates ($75 million); channel dredging ($9 million); agricultural extensions ($2.5 million); South Delta habitat acquisition and restoration ($10 million); mitigation for other project impacts (up to $6 million); fishery investigations ($6 million); indirect effects conservation measure ($2 million).[3]

[2] http://sdip.water.ca.gov/public_outreach/public_meetings/SDIP_Public_Meetings_Presentation.pdf
[3] Ibid.

The CALFED Draft Finance Options Report (Finance Options Report) concluded that increasing the maximum permitted diversion rate to 10,300 cfs would require full screening of Clifton Court Forebay (CCF).[4] The Finance Options Report estimated construction costs to screen CCF could range between $1.1 and $1.4 billion. The Finance Options Report did not provide estimated operational costs of CCFB screens. The Finance Options Report identified a number of pilot and test projects and fishery investigations that would be required prior to implementing full screening of CCFB. Collectively, costs for these projects were expected range between $40 and $75 million.

Estimated capital costs to move from the existing maximum permitted diversion of 6,680 cfs first to 8,500 cfs and then to 10,300 cfs therefore range between $1.25 billion and $1.6 billion. DWR estimated operational costs to move to 8,500 cfs at about $1 million per year. Operational costs of CCF screens are unknown.

This element could entail a range of projects to increase south of Delta CVP/SWP conveyance and storage capacity. Two CVP/SWP interties have been proposed to increase CVP/SWP conveyance capacity and operational flexibility. The Finance Options Report noted that the:

> original design of the Delta Mendota Canal provided for 4,600 cfs diversion from the Delta. The amount, timing and location of water deliveries from the Delta Mendota Canal, apparent canal subsidence, siltation, the facility design, and other factors have resulted in a mismatch between authorized Tracy Pumping Plan export capacity and Delta Mendota Canal conveyance capacity. These factors restrict the full use of the Tracy Pumping Plant. An intertie between the Delta Mendota Canal and the California Aqueduct would allow Tracy pumping at 4,600 cfs by moving about 400 cfs from the Delta Mendota Canal to the California Aqueduct.[5]

The Finance Options Report estimated the cost of an intertie between the Delta Mendota Canal and California Aqueduct to range between $22 and $26 million, exclusive of annual operating and maintenance costs. The Finance Options Report also noted than "[a]n intertie between CCFB and Tracy pumping plant could add operational flexibility to both the CVP and SWP."[6] It estimated the construction cost of this intertie would range between $200 and $400 million. Combined construction costs for the two CVP/SWP interties roughly range between $220 and $425 million. Operational and maintenance costs of the two interties are unknown.

Costs for south-of-Delta storage facilities would depend on type of storage facility (surface or subsurface), size of facility, and location.[7] The CALFED Record of Decision (ROD) objective for groundwater storage is to develop 0.5 to 1.0 million acre-feet of new groundwater storage. Projects being constructed under currently approved grants and loans are expected to exceed the lower limit of 500 TAF of new operable groundwater storage, and may yield about 300 TAF of water supply annually. Costs for these projects were estimated at approximately $1 billion, exclusive of operations and maintenance. Annual operating costs of $55 million were estimated for these projects. Using these figures, the average construction cost per acre-foot of

[4] The following discussion and cost estimates are based on information presented on pages 138-143 of the CALFED Draft Finance Options Report. www.calwater.ca.gov/FinancePlanning/Draft_Finance_Options_Report_5-11-04.pdf

[5] CALFED Draft Finance Options Report, page 141.

[6] Ibid. Page 142.

[7] Cost figures for storage cited in this paragraph are from the CALFED Draft Finance Options Report, pages 100-110.

groundwater storage capacity is about $2,000/AF. The annual cost to operate the facilities is about $183/AF of expected project yield.

Expanding south-of-Delta surface storage would likely entail construction costs in the range of hundreds of millions to billions of dollars. The magnitude of cost would depend on the size and location of the facility. Preliminary cost estimates for the Los Vaqueros Reservoir (LVR) expansion, North of Delta Off-Stream Storage (NODOS), In-Delta Storage, and Upper San Joaquin River (SJR) Basin Storage projects are presented in the following table as examples of the possible ranges and magnitudes of surface storage reservoir projects.[8]

Reservoir Project	Preliminary Cost Range ($ Millions)	Storage Capacity (TAF)
NODOS	$1,300 - $2,300	1,800
In-Delta Storage	$700 - $800	217
LVR Expansion	$870 - $1,300	200 - 400
Upper SJR Basin Storage	$600 - $1,200	450 – 1,200

This bundle would entail a very large capital expense that would likely be irreversible. It would also involve elements (new or increased surface storage, increased Delta pumping capacity) that are likely to be very controversial. Thus, the funding feasibility of this bundle would be relatively low, roughly equivalent to Bundles #4, 5, and 7.

2.3.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Future climate change could result in less snow pack, thus concentrating the period of high runoff and thus reducing the period of time when flexible operation is possible. Implementation of this bundle also relies on maintenance of the existing through-Delta conveyance system, which could be affected by seismic events and island subsidence.

Exporting water opportunistically during high flow events would reduce the need for manipulating Delta in-flow and through Delta channel flows to meet export needs, thus restoring flow-related ecosystem processes to a more natural state during some periods compared to Bundles #1, 2, and 8. Variable hydrology would be restored throughout the Delta during periods that water is not exported or periods when water is exported, but flow volumes are such that pumping has minimal effects on Delta flow patterns. The degree to which variable hydrology is restored will vary depending on inflow conditions during periods that water is exported. The elements of opportunistic water exports would be expected to be highly adaptable to addressing the needs of covered species over time. To the extent that timing of pumping and exports can be managed with predictable outcomes to the species, this bundle is among the most adaptable of the Water Operations and Conveyance bundles.

[8] Surface storage cost and yield estimates are from http://www.publicaffairs.water.ca.gov/newsreleases/2005/Chico_Conf_15apr2005.pdf, slide 19.

The nature and scale of the improvements associated with this bundle, particularly the conveyance and storage facilities would make them relatively irreversible compared to Bundles #1, 2, and 8, but roughly equivalent to Bundles #4-7. Improvements would involve an extensive amount of land disturbance and would be very expensive to remove, if removal were feasible at all. Surface storage facilities would be much less reversible than underground storage facilities.

2.3.4 Other Resource Impacts Criteria (#15-#17)

Exporting water opportunistically during high flow events would partially restore natural hydrologic and salinity conditions in and downstream of the planning area, and would likely improve conditions for native aquatic species both in the Delta and downstream. It would also likely change the distribution and landscape position of native plants. Implementing this bundle would reduce the extent of freshwater riparian and marsh habitat and associated species and expand the extent of brackish water marsh habitat and associated species. Physical loss of terrestrial and wetlands habitat from new conveyance and storage construction south of the Delta could be extensive. Farmed lands that provide forage crops for wildlife (e.g., waterfowl, cranes) could be reduced if this bundle provides for sufficient salinity intrusion to reduce the extent of lands farmed in high value forage crops. The magnitude of these effects to species is expected to be less than under bundles #4-#7.

Construction activities associated with opportunistic exports would have effects related to traffic, air quality, noise, water quality, cultural resources, losses of agricultural land, and other aspects of the human environment. The extent of these adverse effects would depend on the type and extent of storage facilities included in this bundle and there the impacts on the human environment would be either less than or similar to the effects of bundles #4-#8.

2.4 BUNDLE #4: CONSTRUCT AND OPERATE SOUTH DELTA AQUEDUCT (SDA) FACILITIES

Bundle 4 includes elements that involve the construction and operation of a South Delta Aqueduct (SDA) peripheral conveyance facility:

- 4a. Construct and operate a peripheral aqueduct (“South Delta Aqueduct”) from Sacramento River (near Hood) with state of the art screening with discharge into lower San Joaquin River. Diverting water from the Sacramento River near Hood will allow salinities to fluctuate in the western, northern, and eastern Delta. Discharging Sacramento River water into the lower San Joaquin River will improve water quality conditions (e.g., DO) for covered species in the south Delta.

- 4b. Operate the Delta to reestablish fluctuating hydrologic conditions (salinity, flow, temperature) in the northern, western, eastern and central Delta that benefit covered fish species, including re- operation of upstream storage facilities to support Delta operations.

2.4.1 Biological Criteria (#1-#7)

2.4.1.1 Smelt (Delta and longfin)

Operations of a South Delta Aqueduct that diverted water from the Sacramento River that was subsequently discharged into the lower San Joaquin River and exported as the existing SWP and CVP export facilities would be expected to have a low to moderate affect on reducing entrainment vulnerability of Delta and longfin smelt to SWP and CVP export operations. Diversion of water from the Sacramento River at Hood would largely avoid the entrainment of adult, larval, or juvenile Delta smelt, while operation of a state-of-the-art positive barrier fish screen would help further reduce the vulnerability of both Delta and longfin smelt to entrainment. As a result of continued diversion operations from the existing south Delta export facilities Delta and longfin smelt inhabiting the central and southern portion of the Delta would continue to be vulnerable to export operations. Export operations using a South Delta Aqueduct would be expected to have little or no effect on the vulnerability of Delta and longfin smelt to other sources of mortality (e.g., agricultural water diversions) within the Delta (SLC 1).

Operations at the South Delta Aqueduct would be expected to result in a moderate level improvement in Delta hydrodynamics, particularly within central and southern Delta areas associated with Old and Middle rivers. As a result of continued operation of the existing export facilities the South Delta Aqueduct would have little or no effect on local hydrodynamic conditions within those channels currently used for water conveyance to the export facilities located within the southern regions of the Delta. Operation of the aqueduct would allow more variable salinity conditions to occur within the northern, eastern, and western Delta that would have a potential moderate benefit of improving habitat diversity for smelt within the Delta (SLC 2).

The magnitude and potential benefits of South Delta Aqueduct operations on habitat quality and availability within the Delta would vary depending on results and changes in hydrodynamic conditions within various channels, residence time, and the variability of Delta salinity regimes. It is anticipated that these changes would have a low-to-moderate affect on increasing habitat conditions for smelt (SLC 3).

Operation of the South Delta Aqueduct would be expected to have a low-to-moderate affect on increasing food quality and availability through changes in Delta hydrodynamics, increased residence time, and higher habitat diversity as a result of salinity intrusion. Since export operations would continue to occur at the existing facilities food supplies and nutrients produced in the San Joaquin River, as well as elsewhere within the Delta, would continue to be exported (SLC 4).

Operation of the South Delta Aqueduct would be expected to have a low-to-moderate effect on non-native species. Non-native species would continue to be vulnerable to entrainment at the SWP and CVP export facilities as they have in the past, although the variable salinity regime within the Delta may provide incremental benefits to native fish species when compared to non-native species. The relative magnitude of these potential benefits would vary based on changes in hydrodynamic conditions, hydraulic residence time, channel velocities, and seasonal salinity conditions, particularly within the western and central regions of the Delta (SLC 5).

To the extent that operation of the South Delta Aqueduct allows greater salinity intrusion, reduces channel velocities, and improves hydraulic residence time the bundle would contribute to a small-to-moderate level of benefit for ecosystem processes. These potential ecosystem process benefits would be degraded by continued operation of the export facilities from the south Delta (SLC 6).

Design and construction of a state-of-the-art positive barrier fish screen, permitting, and construction of a South Delta Aqueduct would require a substantial amount of time to implement.

2.4.1.2 Sturgeon (green and white)

The construction and operation of a SDA diverting Sacramento River water near Hood, with state of the art fish screening and discharging it into the lower San Joaquin River would have an unknown effect on sturgeon entrainment at the south Delta pumping facilities of the CVP and SWP (SLC 1). It is not known what impact this bundle might have on non-natural mortality of sturgeon.

Changing Delta operations to reestablish fluctuating hydrologic conditions including variation in flows, salinity, and temperature would provide advantages to sturgeon (SLC 2). Actions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas. Flow pulses also act to attract sturgeon to spawning tributaries and aid in juvenile transport downstream. Indications are that those advantages would be offset by the false attraction flows that would result from discharging Sacramento River water into the lower reaches of the San Joaquin River. With the exception of strays from other river systems, sturgeon from the Sacramento-San Joaquin Delta originated in the Sacramento River or one of its tributaries. Available information on sturgeon is limited; nevertheless, spawning sturgeon would likely be confused by false Sacramento River signals in the south Delta. As a result, the negative effects of this element could have a low to moderate population level impact on sturgeon.

We assume that pulse flows in this bundle would be less significant than those described in bundle 3. Providing some flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas (SLC3). Flow pulses also act to attract sturgeon to spawning tributaries and aid in egg survival and juvenile transport downstream. As a result, this element would likely have a low population level impact on sturgeon.

Altering flows to resemble historic hydrologic conditions would likely reduce non-native sturgeon predators (SLC 5). Non-native species currently residing in the Delta are less likely to tolerate fluctuating salinity conditions when compared with native species, which evolved in a fluctuating salinity environment. Allowing parts of the Delta to experience salinity fluctuations would have a moderate benefit to juvenile sturgeon through the reduction of non-native predators. Sturgeon are thought to have a low vulnerability to predation by non-native fish species and therefore this potential benefit is expected to be low.

Using the assumption that altering Delta flows to allow fluctuating conditions in the Delta would be possible as a result of the construction of a SDA, this bundle would not provide benefit to sturgeon in the short-term. This bundle would likely be among the slowest to implement (SLC 7). The cumulative affects of this element are not known.

The effect this bundle on sturgeon population is likely to be slightly negative. Based on the available information, the certainty of this assessment is low.

2.4.1.3 Salmonids

Constructing and operating an SDA facility will likely not reduce non-natural morality from entrainment (SLC 1) and would possibly increase it because there will be two intakes – the SWP/CVP intake and the SDA intake, especially because there are more salmonids outmigrating down the Sacramento River than the San Joaquin River. Although fish screens have been designed that are extremely effective in reducing losses of juvenile salmonids, performance of a large-scale intake located on the Sacramento River are uncertain as a result of the size and site-specific hydrodynamic conditions.

The SDA would likely provide large improvements in water quality for salmonids (SLC 2). Improvements in water quality will have similar impacts to the salmonid populations to those discussed in #2.

The SDA would likely increase the amount of potential juvenile rearing habitat and migration corridors available to salmonids in the north, west, east, and central Delta from re-operation of upstream storage facilities and would allow for more natural hydrologic conditions (SLC 3; see 2.3.1.3). The effect of the SDA would be much greater if habitat restoration in the north, west, east, and central Delta were concurrent with SDA operation. Discharge of Sacramento River water into the San Joaquin River, however, could create false attraction flows and adversely affect Chinook salmon.

The SDA would likely greatly increase food quality, quantity, and accessibility for salmonids (SLC 4). Providing more natural flows would likely give rise to increased abundance of native prey of higher quality. In addition, if floodplains were allowed to flood more naturally, they could provide high levels of productivity into the Delta system. Using a canal to convey water from the Sacramento River across the Delta will improve hydraulic flow patterns and residence times which are expected to result in greater primary and secondary production within the Delta. Water from the San Joaquin River providing nutrients and organic material would continue to be diverted under this bundle. Therefore, the SDA will likely have a moderate beneficial impact on the overall salmonid population because more and better food generally translates into improved fitness.

The SDA could have moderate impacts on reducing abundances of non-native competitors and predators of salmonids (SLC 5) because it may provide conditions not be amenable to non-native species. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives (see #2).

The SDA should improve ecosystem processes related to salmonids (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Salmonids could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation. Further, the SDA would provide the potential for extensive restoration in the north, west, and east Delta because flow and salinity conditions would be natural (see Bundle 18).

Construction of the SDA would be a very long process (SLC 7). Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of salmonids.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.4.1.4 Splittail

Constructing and operating an SDA facility will likely not reduce non-natural morality from entrainment (SLC 1) and would possibly increase it because there will be two intakes – the SWP/CVP intake and the SDA intake. However, mortality at the export facilities is probably very rarely important to the entire population (see 2.1.1.4). Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing splittail mortality.

The SDA would likely provide moderate improvements in water quality for splittail (SLC 2) by allowing fluctuating salinities in the north, east, and west Delta and increasing discharge from the San Joaquin River. Although great improvements in water quality could be predicted, splittail can tolerate a wide range of conditions and, therefore, changes in water quality will have limited effects on overall splittail production, abundance, and distribution. This bundle would provide improved flow conditions for splittail by allowing hydrologic conditions to fluctuate in the north, east, and west, which could allow floodplains and riparian zones to flood naturally. Floodplains and flooded riparian zones are highly favorable spawning habitat for splittail.

The SDA would likely increase the amount of spawning habitat available to splittail in the north, west, east, and central Delta from re-operation of upstream storage facilities and would allow for more natural hydrologic conditions that may support adult populations (SLC 3; see 2.3.1.4).

The SDA would likely greatly increase food quality, quantity, and accessibility for splittail (SLC 4). By isolating the conveyance of water from the Sacramento River through the Delta more natural flow conditions could be created within the Delta having reduced water velocities and longer residence time that would enhance primary and secondary food production. Splittail could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality and an increase in access to prey on floodplains (reproductive splittail often consume earthworms and other terrestrial organisms in floodplains). In addition, floodplains are highly productive and, if flooded, they could provide high levels of productivity into the Delta system. More food allows for greater growth and larger and healthier fish. Therefore, this bundle would likely allow for large positive impacts on the splittail population.

The SDA could have moderate impacts on reducing abundances of non-native competitors and predators of splittail (SLC 5) because it may provide conditions that are not amenable to non-native species. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the Delta planning area are generally resilient to wide variety of environmental conditions. One of the most significant predators on splittail are striped bass that have a broad tolerance of salinity conditions. Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions. This is the nature of invasive species.

The SDA should greatly improve ecosystem processes related to splittail (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem, particularly in the north, central, and western regions of the Delta, to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation. Further, the SDA would likely provide the potential for extensive restoration in the north, west, and east Delta because flow and salinity conditions would be natural (see Bundle 18). The SDA would not be expected to substantially benefit conditions in the south Delta.

Construction of the SDA would likely be a very long process (SLC 7). Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of splittail.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.4.2 Planning Criteria (#8-#10)

The SDA has the capability of meeting the water supply goals of the CVP and SWP PREs. Although the capacity of the aqueduct is not yet know, it is assumed that it would not be constructed unless it met those goals and as such it would be roughly equivalent to Bundles #5-8 in its effectiveness in meeting the PRE's water supply and water quality goals, and better than Bundles #1-3. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

There are a number of unknowns related to the feasibility of the SDA. Among the most important feasibility issues are:

- Can an alignment for the SDA be found (some development has already occurred in the alignment for the originally proposed Peripheral Canal)?
- Is the construction of a peripheral facility politically feasible?
- Will discharging Sacramento River water into the San Joaquin River result in adverse impacts on covered fish species to levels that exceed benefits to covered species?

This element is similar to the "South Delta Restoration Aqueduct" described by the Public Policy Institute of California (PPIC, 2007).[9] As noted by PPIC, no prior cost analyses of this aqueduct configuration have been conducted. PPIC concluded that costs would be similar in magnitude to costs for an isolated facility (IF). As described under Bundle #5 below, costs for a 10,000 cfs IF are expected to range between $2 and $3 billion. These costs are inclusive of fish screens, drainage, siphon, and control structures, but are exclusive of Delta ecosystem support, selected levee improvements and possibly some channel and levee modifications for water quality management. Operational elements of this bundle can be accomplished with existing facilities and therefore do not entail any significant additional capital costs.

This bundle would entail a very large capital expenditure. It would also involve elements (the SDA) that would likely be very controversial. Thus, the funding feasibility of this bundle would be relatively low, roughly equivalent to Bundles #3, 5, and 7.

[9] Public Policy Institute of California: *Envisioning Futures for the Sacramento-San Joaquin Delta*, San Francisco, California, 2007.

2.4.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

This bundle would need to be designed with consideration of potential seismic loading and sea level rise. Conveyance of water from the return point of the SDA on the San Joaquin to CVP and SWP export location will depend on maintaining levee integrity in the south Delta.

Construction and operation of SDA facilities would eliminate the need for manipulating Delta in-flow and through Delta channel flows to meet export requirements in the northern, eastern, western, and central Delta, thus restoring flow-related ecosystem processes in the Delta to a more natural state compared to Bundles #1, 2, 3, and 8. Some flow-related processes in the lower SJR would be improved with the discharge of Sacramento River water into the SJR (e.g., mixing, DO), however, the degree to which these processes are improved would be regulated by export requirements and thus variable. Periodic ongoing human interventions would be required to structural elements of this bundle that support improvements to flow-related ecosystem processes. Because the ability to restore habitats and manage flows in the north, west, east, and central Delta would no longer be constrained by conveyance requirements, this bundle is expected to be highly adaptable to meeting the needs of covered fish species relative to Bundles #1-3, and 8.

Implementation of SDA would represent an extremely large construction project, and would involve a large capital cost. It would be extremely difficult logistically and extremely costly to remove the aqueduct or stop using it once it was constructed. The construction would likely be funded through the issuance of bonds, which would need to be paid back regardless if a revenue stream from water sales was available. So, from a practical perspective, this bundle is considered to be highly irreversible.

2.4.4 Other Resource Impacts Criteria (#15-#17)

Operation of SDA facilities would improve conditions for native aquatic species in the Delta and in the San Joaquin River to a greater extent than under bundles #1, #2, and #3 by restoring more natural hydrologic and salinity conditions throughout a larger portion of the Delta. It would also improve downstream conditions, to a lesser extent. The likely effects on native wildlife and plant occurrences associated with salinity fluctuation would be similar to that as described for bundle #3. Physical loss of terrestrial and wetlands habitat from SDA facility construction would be extensive. The SDA facility would also create a barrier to movement of native species.

Extensive construction associate with bundle #4 would cause large amounts of traffic, noise, and pollutant emissions over a multi-year period. It would also result in direct removal of farmland and the increased salinity of Delta water would result in additional losses of agricultural land use and productivity. This would have local and regional socioeconomic effects. Overall, adverse effects from this bundle would be greater than #1 and #2, less than #6 and #7, and roughly equivalent to #3, #5, and #8.

2.5 BUNDLE #5: CONSTRUCT AND OPERATE AN ISOLATED FACILITY

Bundle 5 includes elements that involve the construction and operation of an isolated peripheral conveyance facility:

- 5a. Construct and operate an isolated facility (IF) (i.e., "peripheral canal") from Sacramento River (near Hood) with state of the art screening directly to the pumps to isolate the Delta from CCF and the SWP/CVP pumps.
- 5b. Operate the Delta to reestablish fluctuating hydrologic conditions (salinity, flow, temperature) throughout the Delta that benefit covered fish species, including re-operation of upstream storage facilities to support Delta operations

2.5.1 Biological Criteria (#1-#7)

2.5.1.1 Smelt (Delta and longfin)

Construction and operation of a state-of-the-art positive barrier fish screen located on the Sacramento River in the vicinity of Hood or Freeport would be expected to virtually eliminate entrainment losses for Delta and longfin smelt. The proposed point of diversion is located near the upstream geographic boundary for smelt, and therefore, the occurrence of various life-history stages of smelt at the point of diversion would be substantially lower than that for the existing export facilities. The isolated facility would eliminate exports from the south Delta, which would further contribute substantially to the avoidance of smelt entrainment losses (SLC 1).

Operation of export facilities with a point of diversion on the Sacramento River would contribute substantially to improvements in both hydrodynamic conditions within the Delta, as well is higher habitat diversity as a result of salinity intrusion. Operation of an isolated facility would allow San Joaquin river flow, as well as flows from the Mokelumne and Cosumnes rivers to pass unimpeded downstream through the Delta. Operation of the export facilities at Hood would also allow re-establishment of natural flow conditions within the Delta channels that would contribute to increased residence time and reduce channel velocities, particularly within Old and Middle rivers located within the south region of the Delta, that would provide biological benefit. Re-establishing a more dynamic salinity regime would also provide habitat benefits through increased habitat diversity within the Delta. A key element of assessing the biological effects of an isolated facility would be determined by the operations plan for the diversion structure. Issues associated with the relative magnitude of diversions from the Sacramento River at Hood, compared to the Sacramento River flow would need to be addressed and a downstream bypass flow criterion established to ensure that habitat conditions for smelt within the Sacramento River downstream of the point of diversion continue to be suitable (SLC 2).

Operation of an isolated facility would provide an incremental benefit to habitat quality and availability within the Delta in the form of both improved hydrodynamic conditions as well as salinity conditions. The isolated facility would not, in and of itself, result in physical habitat improvements within the Delta other than those associated with hydrodynamic and water quality conditions (SLC 3).

Operation of an isolated diversion facility at Hood would result in a substantial improvement in food availability and nutrients within the Delta. The substantial increase in food availability and nutrients would result from several factors including the diversion of Sacramento River water that typically has lower nutrient loading when compared to those waters from the San Joaquin River and Delta. Furthermore, operation of the isolated facility would contribute to reduced channel velocities in increased residence time that would directly contribute to improvements in the production and abundance of phytoplankton and zooplankton within the Delta. The isolated conversion facility would allow San Joaquin River water as well is waters from the Mokelumne and Cosumnes rivers and those from the Delta to deliver nutrients to the estuary and promote primary and secondary production (SLC 4).

The effects of the isolated facility on non-native species are uncertain. Operation of an isolated facility with a positive barrier fish screen would significantly reduce the vulnerability of non-native fish species to entrainment losses and therefore would be expected to contribute to an increase in abundance of non-native species when compared to current conditions. Increased food availability, reduced channel velocities, and increased residence time may also provide habitat conditions that are favorable for both native and non-native species. Increased salinity intrusion and variable salinity regimes are thought to favor native fish species through increased habitat diversity and complexity, however the overall biological response of non-native and native fish communities and other elements of the aquatic community to variable salinity regimes, are uncertain. Many of the non-native species with low salinity tolerance may simply move their geographic distribution further upstream where they would continue to prey and compete with native species. Many of the other non-native species may have a broad salinity tolerance and therefore may not be adversely affected by a variable salinity regime (SLC 5).

Operation of an isolated facility would substantially contribute to improvements in ecosystem processes within the Delta, primarily those associated with hydrodynamics, residence time, channel velocities, and a more dynamic and variable salinity merging (SLC 6).

Design, permitting, and construction of a state-of-the-art positive barrier fish screen and isolated conveyance facility is anticipated to require a decade or longer for implementation.

2.5.1.2 Sturgeon (green and white)

The construction and operation of an isolated facility diverting Sacramento River water near Hood, with state of the art fish screening and discharging it into Clifton Court Forebay would have a beneficial effect on the non-natural mortality of sturgeon (SLC 1). Under the assumption that the new Sacramento River intake facility will not entrain juvenile sturgeon, impacts to sturgeon related to the current operation of Clifton Court Forebay would be nearly eliminated. Modifications that reduce non-natural mortality in this element would likely have low to moderate beneficial effects on sturgeon population abundance.

Providing flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve spawning area quality by cleaning bed material (SLC 2). Reestablishing natural pulse patterns that would have occurred following storm events would be beneficial. The isolated conveyance facility would allow flows within the Delta to return to a more natural tidal regime with net westerly flows. This change in water velocities and residence times would be expected to benefit juvenile rearing as well as adults through improve habitat quality and increased prey availability. This element would have a moderate population level effect on sturgeon.

Providing flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas (SLC3). Flow pulses also act to attract sturgeon to spawning tributaries and aid in egg survival and juvenile transport downstream. As a result, this element would likely have a moderate population level impact on sturgeon.

Reestablishing historical hydrologic conditions could affect sturgeon food quality and quantity, but that impact is not known (SLC 4). This bundle is expected to return flows within the Delta to a more natural condition. Reduced channel velocities and increased residence times would be expected to result in increased primary and secondary food production that would benefit sturgeon.

Altering flows to resemble historic hydrologic conditions would likely reduce non-native sturgeon predators (SLC 5). Non-native species currently residing in the Delta are less likely to tolerate fluctuating salinity conditions when compared with native species, which evolved in a fluctuating salinity environment. Allowing parts of the Delta to experience salinity fluctuations would have a low benefit to juvenile sturgeon through the reduction of non-native predators, since juvenile and adult sturgeon have a reduced vulnerability to predation.

Using the assumption that altering Delta flows to allow fluctuating conditions in the Delta would be possible as a result of the construction of an isolated facility this bundle would not provide benefit to sturgeon in the short-term. This bundle would likely be among the slowest to implement due to the time required to construct the proposed facilities (SLC 7).

The cumulative effects this action are expected to be low to moderate. Based on the available information, the certainty of the assessment of this bundle is low.

2.5.1.3 Salmonids

Construction and operation of the IF would eliminate entrainment mortality of salmonids in the south Delta (e.g., San Joaquin River salmon), but would increase entrainment mortality at the intake of the IF at Hood (SLC 1), especially because the abundance of salmonids is generally greater near Hood compared to the south Delta. It is expected that a well designed and operated positive barrier fish screen will be approximately 95% effective in avoiding salmonid losses. Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing salmonid mortality. Thus, overall, the IF may cause substantial reductions in net salmonid mortality. The impact of these reductions in mortality to overall populations are uncertain.

The IF has great potential to increase water quality and flow conditions (SLC 2) in the planning area because there will be no need to have a hydrologic barrier to keep salinity low in the south Delta. Improvements in water quality will have similar impacts to the salmonid populations to those discussed in #2, but will likely be greater. Operation of an isolated facility would allow natural flows through the Delta (net westerly flows), would eliminate reverse flows associated with export operations, and would allow the San Joaquin River and other Delta tributaries to flow unimpeded through the Delta.

The IF would likely greatly increase the quality and quantity of juvenile salmonid rearing habitat and migration corridors throughout the Delta (SLC 3; see 2.3.1.3). This effect will be greater than that of the SDA (#4).

The IF would likely greatly increase food quality, quantity, and accessibility for salmonids (SLC 4). Salmonids could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality and an additional productivity from floodplain flooding. Avoiding the conveyance of export flows through the Delta will increase residence time and reduce channel current velocities that will contribute to improved production. This effect of this bundle on food abundance, quality, and accessibility will likely have a large effect on the overall salmonid population.

The IF could have moderate impacts on reducing abundances of non-native competitors and predators of salmonids (SLC 5) because it may provide conditions not be amenable to non-native species. In contrast, since entrainment mortality at the existing SWP and CVP intakes would be substantially reduced, survival of non-native fish species would be expected to increase resulting in potentially higher population abundance. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives (see #2).

The IF should greatly improve ecosystem processes related to salmonids (SLC 6) in a similar way to the SDA (#4) but even more. A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Salmonids could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation. Further, the IF would provide the potential for extensive restoration throughout the Delta because flow and salinity conditions would be natural (see Bundles 18-20). Overall, this BO would likely provide the best conditions for salmonids (particularly in the south Delta) because it is the most natural.

Construction of the IF would be a very long process (SLC 7). Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of salmonids.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.5.1.4 Splittail

Construction and operation of the IF would eliminate entrainment mortality of splittail in the south Delta. Operation of a positive barrier fish screen on the Sacramento River would substantially reduce or eliminate entrainment of juvenile and adult splittail. Early larval stages (less than approximately 15 mm in length) would still be vulnerable to entrainment through the fish screen. (SLC 1). Assuming similar abundances of splittail at both locations, there would be a substantial net reduction in entrainment because the IF would have state of the art screening on the intakes. However, as stated above, mortality at the pumps is not expected to be great enough in most years to affect overall population abundance such that construction of the IF will have only moderate reductions in splittail mortality and population dynamics. Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing splittail mortality. Reductions in mortality from this bundle could be greater than the other water operations and conveyance bundles.

The IF likely has maximum potential to increase water quality and flow conditions (SLC 2) in the planning area because there will be no need to have a hydrologic barrier to keep salinity low in the south Delta. However, the increase in water quality will have limited effects on splittail owing to their tolerance of a wide range in salinity, temperature, and DO.

The IF would likely greatly increase the quality, quantity, and accessibility of splittail habitat throughout the Delta, including spawning, juvenile rearing, and adult habitat (SLC 3; see 2.3.1.4).

The IF would likely greatly increase food quality, quantity, and accessibility for splittail (SLC 4). Splittail could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality and an increase in access to prey on floodplains (reproductive splittail often consume earthworms and other terrestrial organisms in floodplains). In addition, floodplains are highly productive and, if flooded, they could provide high levels of productivity into the Delta system. More food allows for greater growth and larger and healthier fish. Therefore, this bundle would likely allow for large positive impacts on the splittail population.

The IF could have moderate impacts on reducing abundances of non-native competitors and predators of splittail (SLC 5) because it may provide conditions that are not amenable to non-native species. Fluctuating salinities, however, are not expected to have a substantial effect on striped bass, which are among the predators foraging on splittail. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the Delta planning area are generally resilient to wide variety of environmental conditions. Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions. This is the nature of invasive species.

The IF should greatly improve ecosystem processes related to splittail (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation. Further, the IF would provide the potential for extensive restoration throughout the Delta because flow and salinity conditions would be natural (see Bundles 18-20). Overall, this BO would likely provide the best conditions for splittail (particularly in the south Delta) because it is the most natural.

Construction of the IF would likely be a very long process (SLC 7). Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of splittail.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.5.2 Planning Criteria (#8-#10)

The Isolated Facility has the capability of meeting the water supply goals of the CVP and SWP PREs. Although the capacity of the aqueduct is not yet know, it is assumed that it would not be constructed unless it met those goals. Bundle #5 would be equal or better than Bundles #4 and 6 in its effectiveness in meeting PRE water supply and water quality planning goals, somewhat better than Bundles #7 and 8, and much better than Bundles #1-3. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

There are a number of unknowns related to the feasibility of the Isolated Facility. Among the most important feasibility issues are:

- Can an alignment for the aqueduct be found (some development has already occurred in the alignment for the original Peripheral Canal)?
- Is the construction of an isolated facility politically feasible?

The most current cost estimates to construct an IF from the Sacramento River (near Hood) to the SWP/CVP pumps were prepared for CALFED in 1999.[10] The Public Policy Institute of California (PPIC) summarized and updated these cost estimates to 2006 dollars in 2007.[11] Planning and construction costs are estimated to range between $2 and $3 billion for a 10,000 cfs incised earthen canal complete with fish screens, drainage, siphon, and control structures. PPIC notes this cost estimate "does not include costs for Delta ecosystem support, selected urban levee improvements, and possibly also some other levees or channel modifications to prevent deterioration of water quality within the Delta that would accompany this program." Operations components of this bundle can be accomplished with existing facilities and therefore do not entail any significant additional capital costs.

This bundle would entail a very large capital expense. It would also involve elements (the Isolated Facility) that would be very controversial. Thus, the funding feasibility of this bundle would be relatively low, roughly equivalent to Bundles #3, 4, 6, and 7.

2.5.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Unlike Bundles 1-4 and 6-8, Bundle #5 is not dependent on the stability of Delta levees to maintain conveyance to and water quality at the SWP/CVP pumps. While the aqueduct itself could be at risk of failure from a seismic event, the risk of such failure is much less than the risk of in-Delta levee failures that would severely limit operations under Bundles #1-4 and #8. Sea level rise would have little effect on meeting the PRE's water quality objectives at the SWP/CVP pumps.

Construction and operation of an isolated facility would eliminate the need for manipulating Delta in-flow and through Delta channel flows to meet export requirements throughout the Delta, thus restoring flow-related ecosystem processes to a more natural state during some periods compared to Bundles #1-4 and 6-8. Periodic ongoing human interventions would be required to maintain the isolated conveyance facilities that support improvements to flow-

[10] CALFED, *Isolated Facility: Conceptual Analysis of Incised Canal Configuration,* Sacramento, California, September 1999.

[11] PPIC (2007)

related processes. Because the opportunity to restore habitats and manage flows throughout the Delta would no longer be constrained by water supply conveyance requirements this bundle is considered to be the most adaptable for meeting the needs of covered fish species relative to the other water operations and conveyance bundles.

This bundle would represent large construction project, and involve a large capital cost. It would be difficult logistically and costly to remove the aqueduct or stop using it once it was constructed. The construction would likely be funded through the issuance of bonds, which would need to be paid back regardless if a revenue stream from water sales was available. So, from a practical perspective, this bundle is considered to be highly irreversible.

2.5.4 Other Resource Impacts Criteria (#15-#17)

Construction and operation of an isolated facility would likely improve conditions for native aquatic species within the planning area and downstream of the Delta to a greater extent than under the other operations bundles because it would more fully restore variable hydrologic and salinity conditions throughout the Delta and completely avoid entrainment mortality in the south Delta. The likely effects on freshwater adapted native wildlife and plants associated with salinity fluctuation would be greater than that for other operational bundles as a larger proportion of the Delta could be allowed to support fluctuating hydrology and salinity. Physical loss of terrestrial and wetlands habitat from isolated facility construction would be extensive.. Loss of habitat for other native species would be more than under Bundles #1-#3 and #8; similar to Bundle #4; and less than under Bundles #6 and #7. Construction of the peripheral canal would also create a barrier to the movement of native terrestrial wildlife. Farmed lands that provide forage crops for wildlife (e.g., waterfowl, cranes) could be reduced if this bundle provides for sufficient salinity intrusion to reduce the extent of lands farmed in high value forage crops. This effect would be likely greater under this bundle than Bundles #4, 6, and 7 because the entire Delta would be subjected to fluctuating salinities.

The activities included in Bundle #5 would result in impacts to the human environment roughly equivalent to Bundle #4.

2.6 BUNDLE #6: CONSTRUCT AND OPERATE A BIFURCATED SDA

Bundle 6 includes elements that involve the construction and operation of a bifurcated SDA conveyance facility:

- 6a. Construct and operate a peripheral aqueduct from the Sacramento River (near Hood) with state of the art screening that is bifurcated at the discharge end: one split discharges into the CCF and isolates the SWP and CVP pumps (smaller discharge than under Bundle #5), and the other split discharges into lower San Joaquin River (smaller discharge than under Bundle #4). Diverting water from the Sacramento River near Hood will allow salinities to fluctuate throughout the Delta. Discharging Sacramento River water into the lower San Joaquin River will improve water quality conditions (e.g., dissolved oxygen) for covered species in the south Delta.

- 6b. Operate the Delta to reestablish fluctuating hydrologic conditions (salinity, flow, temperature) that benefit covered fish species, including re-operation of upstream storage facilities to support Delta operations in northern, western, eastern, and central Delta.

- 6c. Limited exports continued from existing South Delta facilities

2.6.1 Biological criteria (#1-#7)

2.6.1.1 Smelt (Delta and longfin)

To the extent that SWP and CVP exports are supplied solely from the isolated portion of a bifurcated aqueduct, the benefits for smelt in reducing entrainment mortality would be comparable to those discussed under Bundle #5. To the extent that diversion operations included both water supplied from the isolated facility, as well as diversions from the south Delta using the existing diversion facilities, the biological benefit of reduced smelt entrainment would be diminished (SLC 1).

The conveyance and introduction of Sacramento River water into the lower San Joaquin River would result in localized changes in both hydrodynamics and water quality conditions. The use of the isolated facility would allow for improvements in hydrodynamic conditions within the Delta as discussed in Bundle #5. To the extent that the discharge of Sacramento River water into the lower San Joaquin River provides olfactory or other environmental cues affecting upstream movement of smelt, which is largely unknown, there is the potential risk of false attraction of adults smelt (pre-spawning) into the lower San Joaquin River. These potential effects, however, are unknown. Introducing a more variable salinity regime is expected to result in increased habitat diversity and complexity and is thought to benefit smelt. The absolute benefit of these changes in hydrodynamic and water quality conditions on quality and availability of habitat for smelt will vary based on the operational characteristics of Bundle #6 (SLC 2).

Although operation of the isolated facility, in combination with conveyance and discharges into the lower San Joaquin River will improve hydrodynamic conditions in water quality within the estuary, these changes would contribute to an incremental benefit to increased habitat quality and availability for smelt. The proposed facilities in Bundle #6, however, would not affect physical habitat conditions within the Delta other than through their incremental benefits associated with hydrodynamics and water quality (SLC 3).

As discussed under Bundle #5, diverting water from an isolated facility with the point of conversion located on the Sacramento River offers a substantially improved condition for food supplies and nutrient loading to the Delta. Improvements in hydrodynamics and residence time, as well as the contribution of nutrients and organic material from Delta tributaries, would be expected to significantly improve both primary and secondary production within the Delta (SLC 6).

As noted for Bundle #5 the effects of operation of an isolated facility on the relative abundance of native- and non-native species is largely unknown (SLC 5).

Operation of the isolated facility and re-establishment of natural flow regimes within the Delta, and enhanced flow in the lower San Joaquin River, would be expected to contribute substantially to improvements in ecosystem processes. The improvements in ecosystem processes under Bundle #6, however, would be expected to be reduced when compared to those under Bundle #5 as a result of the artificial conveyance and discharge of water from the Sacramento River into the lower San Joaquin River. Artificial improvement of water quality and hydrodynamics in the lower San Joaquin River would be expected to alter natural ecosystem processes within the central and southern portions of the Delta (SLC 6).

Design, permitting, and construction of a bifurcated south Delta aqueduct facility is expected to take a decade or longer for full implementation (SLC 7).

2.6.1.2 Sturgeon (green and white)

The construction and operation of a SDA diverting Sacramento River water near Hood, with state of the art fish screening and a bifurcated discharge delivering water into both the lower San Joaquin River and Clifton Court Forebay would likely result in less non-natural sturgeon mortality by reducing CVP/SWP entrainment (SLC 1). Since the Forebay would continue to be used to draw water from the south Delta, entrainment would likely be reduced but not eliminated as in the isolated facility bundle (5). Modifications that reduced non-natural mortality in this element would likely have low beneficial effects on sturgeon population abundance.

Changing Delta operations to reestablish fluctuating hydrologic conditions including variation in flows, salinity, and temperature would provide advantages to sturgeon (SLC 2). Actions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas. Flow pulses also act to attract sturgeon to spawning tributaries and aid in juvenile transport downstream. Indications are that those advantages would be offset by the false attraction flows that would result from discharging Sacramento River water into the lower reaches of the San Joaquin River. With the exception of strays from other river systems, sturgeon from the Sacramento-San Joaquin Delta originated in the Sacramento River or one of its tributaries. Available information on sturgeon is limited; nevertheless, spawning sturgeon would likely be confused by false Sacramento River signals in the south Delta. As a result, the negative effects of this element could have a moderate population level impact on sturgeon.

We assume that pulse flows in this bundle would be less significant than those described in bundle 3. Providing some flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas (SLC3). Flow pulses also act to attract sturgeon to spawning tributaries and aid in egg survival and juvenile transport downstream. As a result, this element would likely have a low to moderate population level impact on sturgeon.

Altering flows to resemble historic hydrologic conditions would likely reduce non-native sturgeon predators (SLC 5). Non-native species currently residing in the Delta are less likely to tolerate fluctuating salinity conditions when compared with native species, which evolved in a fluctuating salinity environment. Allowing parts of the Delta to experience salinity fluctuations would have a low benefit to juvenile sturgeon through the reduction of non-native predators since they have a reduced vulnerability to predation mortality.

Using the assumption that altering Delta flows to allow fluctuating conditions in the Delta would be possible as a result of the construction of a SDA with a bifurcated discharge, this bundle would not provide benefit to sturgeon in the short-term. This bundle would likely be among the slowest to implement due to the time required to construct the proposed facilities (SLC 7).

The cumulative affects of this bundle on sturgeon populations are expected to be low to moderate. Based on the available information, the certainty of the assessment of this bundle is low.

2.6.1.3 Salmonids

Constructing and operating a bifurcated SDA facility will likely reduce non-natural morality of salmonids from entrainment (SLC 1). The diversion point on the Sacramento River would be equipped with a positive barrier fish screen (these screens have been found to be effective in reducing and avoiding salmonid losses). To the extent that water is also diverted from the existing export facilities the benefits of this bundle would be diminished. However, mortality at the pumps is important to the entire population very rarely (see 2.1.1.3). Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing salmonid mortality. Reductions in mortality from this bundle could be greater than Bundle #2, depending on how much of a reduction in water demand and Delta diversion exists, possibly lower than Bundles 1 and 3, but will likely fall somewhere in the range of the other water operations and conveyance bundles.

The bifurcated SDA would likely provide large improvements in water quality for salmonids (SLC 2). Improvements in water quality will have similar impacts to the salmonid populations to those discussed in #2, but even greater because of increased through Delta water movement. These effects will also be greater than implementation of the SDA alone (#4).

The bifurcated SDA would likely increase the amount of potential juvenile rearing habitat and migration corridors available to salmonids in the north, west, east, and central Delta from re-operation of upstream storage facilities and would allow for more natural hydrologic conditions (SLC 3; see 2.3.1.3). The effect of the SDA would be much greater if habitat restoration in the north, west, east, and central Delta were concurrent with SDA operation. These effects will also be greater than implementation of the SDA alone (#4). As described for Bundle #4, discharge of Sacramento River water into the lower San Joaquin River could create false attraction flows and adversely affect Chinook salmon. The degree of this affect, however, may be somewhat less under this bundle than under Bundle #4 because smaller volumes of water would be discharged into the San Joaquin River.

The bifurcated SDA would likely greatly increase food quality, quantity, and accessibility for salmonids (SLC 4) in a way similar to the SDA alone (#4) but better because it will provide better east to west flows.

The bifurcated SDA could have moderate impacts on reducing abundances of non-native competitors and predators of salmonids (SLC 5) because it may provide conditions that are not amenable to non-native species. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives (see #2).

The bifurcated SDA should greatly improve ecosystem processes related to salmonids (SLC 6) similar to the SDA alone (#4) but better because it will provide better east to west flows.

Construction of a bifurcated SDA would likely take the longest of the bundles other than Bundle 8 because there are two branches near the end of the SDA. Therefore, this bundle is likely the second lowest in its ability to be implemented with in a time frame to meet the near-term needs of salmonids.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.6.1.4 Splittail

Constructing and operating a bifurcated SDA facility will likely not reduce non-natural morality from entrainment (SLC 1) and would possibly increase it because there will be two intakes – the SWP/CVP intake and the SDA intake. To the extent that diversions a made using the isolated conveyance facility this bundle would substantially reduce or avoid mortality. These benefits would be reduced to the extent that diversions are made from the existing south Delta export faculties. However, mortality at the pumps is very rarely important to the entire population (see 2.1.1.4). Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing splittail mortality. The effect of reducing predation mortality by a fluctuating salinity regime is reduced since striped bass have a high tolerance to salinity and would not be expected to be reduced by this action. Reductions in mortality from this bundle could be greater than Bundle 2, depending on how much of a reduction in water demand and Delta diversion exists, possibly lower than Bundles 1 and 3, but will likely fall somewhere in the range of the other Bundles.

The bifurcated SDA would likely provide moderate improvements in water quality for splittail (SLC 2) by allowing fluctuating salinities in the north, east, and west Delta and increasing discharge from the San Joaquin River. Although great improvements in water quality could be predicted, splittail can tolerate a wide range of conditions and, therefore, changes in water quality will have limited effects on overall splittail production, abundance, and distribution. This bundle would provide highly improved flow conditions for splittail by allowing hydrologic conditions to fluctuate in the north, east, and west, which could allow floodplains and riparian zones to flood naturally. Floodplains and flooded riparian zones are highly favorable spawning habitat for splittail.

The bifurcated SDA would likely increase the amount of spawning habitat available to splittail from re-operation of upstream storage facilities and would allow for more natural hydrologic conditions that may support adult populations (SLC 3; see 2.3.1.4).

The bifurcated SDA would likely greatly increase food quality, quantity, and accessibility for splittail (SLC 4). Reduced channel velocities and increased residence times within the Delta would be expected to result in increased food production. Splittail could potentially benefit from more natural flows because this may give rise to increased abundance of native prey of higher quality and an increase in access to prey on floodplains (reproductive splittail often consume earthworms and other terrestrial organisms in floodplains). In addition, floodplains are highly productive and, if flooded, they could provide high levels of productivity into the Delta system. More food allows for greater growth and larger and healthier fish. Therefore, this bundle would likely allow for great positive impacts on the splittail population.

The bifurcated SDA could have a low impact on reducing abundances of non-native competitors and predators of splittail (SLC 5) because it may provide conditions not be amenable to non-native species. In contrast, to the extent that diversions are made using the isolated facility, entrainment mortality to non-native fish species would be reduced and may result in increased abundance. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the Delta planning area are generally resilient to wide variety of environmental conditions (e.g., striped bass). Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions. This is the nature of invasive species.

The bifurcated SDA should greatly improve ecosystem processes related to splittail (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation. Further, the bifurcated SDA would provide the potential for extensive restoration in the north, west, and east Delta because flow and salinity conditions would be natural (see Bundle 18). This bundle will likely improve ecosystem processes in the Delta at a level greater than Bundle 4 (because of limited CVP/SWP pumping), but not as great as Bundle 5 (because there is still pumping in the Delta).

Construction of a bifurcated SDA would likely take the longest of the water conveyance and operations bundles other than Bundle 8 because there are two branches near the end of the SDA. Therefore, this bundle is likely the second lowest in its ability to be implemented with in a time frame to meet the near-term needs of splittail.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.6.2 Planning criteria (#8-#10)

The Bifurcated SDA has the capability of meeting the water supply goals of the CVP and SWP PREs. Moving the point of diversion to the north Delta could reduce the adverse effects of the export diversions on the Covered Species and on the ecosystem as a whole. If that proves true, export levels could be maintained at current levels or even greater levels than present, while reducing take of covered species. It would be roughly equivalent to Bundles #4 and #5 in its effectiveness in meeting these goals, somewhat better than Bundles #7 and 8, and much better than Bundles #1-3. This outcome, however, may be less likely for this bundle than the other bundles that include isolated facilities if discharging Sacramento River water into the San Joaquin River has substantial adverse effects on some covered fish species. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

There are a number of unknowns related to the feasibility of the Bifurcated SDA. Among the most important feasibility issues are:

- Can an alignment for the aqueduct be found (some development has already occurred in the alignment for the original Peripheral Canal)?
- Is the construction of an isolated facility politically feasible?
- Will discharging Sacramento River water into the San Joaquin River result in adverse impacts on covered fish species to levels that exceed benefits to covered species?

This bundle is a hybrid of Bundles #4 and #5. Costs for those two bundles are expected to be comparable and range between $2 and $3 billion, exclusive of Delta ecosystem support, selected levee improvements and possibly some channel and levee modifications for water quality management. Planning and construction costs for would likely be higher than for Bundles #4 and #5 due to bifurcation of the canal at the discharge end. The extent to which bifurcation would increase land acquisition and construction costs is not known with any degree of certainty. Bifurcation might increase miles of canal construction by 10% to 50% depending on configuration and location of the SJR discharge point, would necessitate construction of two discharge facilities, and would forego some economies of scale associated with a single, higher capacity aqueduct. Operational elements of this bundle can be accomplished with existing facilities and therefore do not entail any significant additional capital costs.

This bundle would entail the largest capital expense of any of the Water Operations and Conveyance bundles. It would also involve elements (a Bifurcated Isolated Facility) that would be very controversial. Thus, the funding feasibility of this bundle would be the lowest of any of the Water Operations and Conveyance bundles.

2.6.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

This bundle would need to be designed with consideration of potential seismic loading and sea level rise. Conveyance of water from the return point of the SDA on the San Joaquin to CVP and SWP export location will depend on maintaining levee integrity in the south Delta.

Construction and operation of bifurcated SDA facilities would eliminate the need for manipulating Delta in-flow and through Delta channel flows to meet export requirements in the northern, eastern, western, and central Delta, thus restoring flow-related ecosystem processes to a more natural state during some periods compared to Bundles #1, 2, and 8.

Because water would continue to be exported from the south Delta pumps, but at reduced levels from Bundle #4, periods during which flow-related ecological process supported by the natural hydrograph can operate in the south Delta would be less than under Bundles #3 and #5. The evaluation of flow-related processes related to the discharge of Sacramento River water into the lower San Joaquin River would be improved to a lesser degree that described for Bundle #4 because lesser volumes of water would be discharged into the San Joaquin River. Periodic ongoing human interventions would be required to maintain structural elements that support improvements to flow-related ecological processes. Because the ability to restore habitats and manage flows in the north, west, east, and central Delta would no longer be constrained by conveyance requirements, this bundle is expected to be highly adaptable to meeting the needs of covered fish species relative to Bundles #1-3, 7 and 8.

Implementation of a bifurcated SDA would represent an extremely large construction project, and would involve a large capital cost. It would be extremely difficult logistically and extremely costly to remove the aqueduct or stop using it once it was constructed. The construction would likely be funded through the issuance of bonds, which would need to be paid back regardless if a revenue stream from water sales was available. So, from a practical perspective, this bundle is considered to be highly irreversible.

2.6.4 Other Resource Impacts Criteria (#15-#17)

Construction and operation of bifurcated SDA facilities would have the same effects on other native species in and downstream of the Delta as described for bundle #4. They would also likely be affected in the south Delta as described under bundle #5, but probably to a lesser degree. The activities included in Bundle #6 would involve and extensive amount of construction, and could result in the physical loss of habitat for native riparian, wetland, and terrestrial species along the conveyance corridor and at diversion facilities. Loss of habitat for other native species is likely to be more than under the other water conveyance and operations bundles. Construction of the canals would also create a barrier to the movement of native terrestrial wildlife.

The activities included in Bundle #6 would involve an extensive amount of construction, more than the Bundle #4 SDA or Bundle #5 Isolated Facility (because of its slightly greater length). It would also result in impacts to the human environment (noise, traffic, emissions pollutants, farmland loss) higher than any of the other Water Operations and Conveyance bundles.

2.7 BUNDLE #7: CONSTRUCT AND OPERATE DUAL CONVEYANCE FACILITIES

Bundle 7 includes elements that involve the construction and operation of dual (through-Delta and peripheral) conveyance facilities:

- 7a. Improvements/maintenance of through Delta conveyance facilities (e.g., reinforcing levees, dredging to maintain channel capacity).
- 7b. Construct and operate a peripheral aqueduct from Sacramento River (near Hood) of lesser capacity than under Bundle #5 directly to the pumps to isolate the Delta from CCF and the SWP/CVP pumps.
- 7c. Operate the Delta to reestablish fluctuating hydrologic conditions (salinity, flow, temperature) that benefit covered fish species, though not to the extent under Bundle #4 and 5, including re-operation of upstream storage facilities to support Delta operations

2.7.1 Biological Criteria (#1-#7)

2.7.1.1 Smelt (Delta and longfin)

Reduction in smelt entrainment losses under Bundle #7 would be similar to those described for Bundle #6 (SLC 1). Changes in water quality and hydrodynamic conditions would be similar to those described under Bundle #6 with the exception that Sacramento River water would not be preferentially converted in the lower San Joaquin River, but rather would flow through existing channels. Reinforcing levees and promoting flow from the Sacramento River through the Delta would contribute to a reduction in hydrologic benefits of Bundle #7 when compared to Bundle #6 (SLC 2).

Changes in habitat quality and availability would be expected to be similar or less than those described for Bundle #6 (SLC 3). As a result of the increased flows through existing Delta channels it would be expected under Bundle #7 that channel velocities would increase and hydraulic residence time would be reduced when compared to Bundle #6. Therefore the potential biological benefits on food production and supplies within the Delta would be expected to be reduced under Bundle #7, when compared to habitat conditions under Bundle #6 (SLC 4).

Changes in the balance of native- and non-native species under Bundle #7 would be similar to those expected under Bundle #6 (SLC 5). Changes in ecosystem processes under Bundle #7 would be expected to be similar or less than those under Bundle #6. Although Bundle #7 would reduce the potential effects of discharge of Sacramento River water into the lower San

Joaquin, the physical facilities and operations under Bundle #7 would continue to increase the flow of Sacramento River water through Delta channels and affect ecosystem processes such as those associated with hydraulic residence time (SLC 6).

Design, permitting, and construction of the bifurcated facility would be expected to be similar to that described for Bundle #6. Under Bundle #7, however, interim actions designed to increase channel armoring and the flow of water through the Delta channels may occur on a shorter-term basis (years).

2.7.1.2 Sturgeon (green and white)

The construction and operation of Dual Conveyance facilities could reduce non-natural mortality of sturgeon by reducing entrainment at the south Delta pumping facilities of the CVP and SWP (SLC 1). The salvage of juvenile sturgeon at the pumps of the CVP and SWP is relatively low in part due to the fact that sturgeon are demersal and that they tend to inhabit regions of the Delta closer to their origin, the Sacramento River. Dredging of channels to accommodate improved through Delta conveyance could negatively impact sturgeon. Columbia River studies have shown that dredging can cause mortality of sturgeon. The benefit of this bundle to sturgeon would vary based on the use of the isolated conveyance facility. The greater the use of the isolated facility the greater the potential benefit relative to current conditions or diversions from the South Delta under this bundle. As a result, there would likely be a net positive effect of these elements to the sturgeon population, depending on operations.

Changing Delta operations to reestablish fluctuating hydrologic conditions including variation in flows, salinity, and temperature would provide advantages to sturgeon (SLC 2). Actions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas. Flow pulses also act to attract sturgeon to spawning tributaries and aid in juvenile transport downstream. Turbidity associated with dredging could have a localized short-duration negative effect on food web dynamics and sturgeon feeding. As a result, the negative effects of this element could have a low to moderate population level impact on sturgeon.

Providing flows to improve flow related habitat conditions to mimic historical hydrologic patterns can improve access to spawning and juvenile rearing areas (SLC3). Flow pulses also act to attract sturgeon to spawning tributaries and aid in egg survival and juvenile transport downstream. Since this flow fluctuation would be done at a lesser extent than in bundles 4 and 5, the resulting benefit will be less. Dredging of channels to accommodate improved through Delta conveyance could negatively impact sturgeon. There is a relatively high degree of uncertainty in the response of sturgeon to these actions. As a result, this element would likely have a moderate population level impact on sturgeon.

Dredging of Delta channels to accommodate through Delta conveyance will likely have a short-duration localized negative impact on the sturgeon food supply (SLC 4). Sturgeon are demersal and are essentially bottom feeders, subsequently dredging operations, depending upon the extent and location, could significantly affect the availability of sturgeon prey species.

Attempting to duplicate historic hydrologic conditions would likely reduce non-native sturgeon predators (SLC 5). Non-native species currently residing in the Delta are less likely to tolerate fluctuating salinity conditions when compared with native species, which evolved in a fluctuating salinity environment. Allowing parts of the Delta to experience salinity fluctuations would have a low benefit to juvenile sturgeon through the reduction of non-native predators given the low vulnerability to predation, but will likely be less than the benefit derived by bundles 4 and 5 which alter flows to a greater degree.

Using the assumption that altering Delta flows to allow fluctuating conditions in the Delta would be possible as a result of the construction of a isolated conveyance canal and the improvement of through Delta conveyance, this bundle would not provide benefit to sturgeon in the short-term. This bundle would likely be among the slowest to implement due to the time required to construct the proposed facilities (SLC 7).

The cumulative affects this bundle are expected to be negative, but to a low degree. Based on the available information, the certainty of the assessment of this bundle is low.

2.7.1.3 Salmonids

Constructing and operating dual conveyance facilities would have limited reductions on salmonid mortality. This action would likely reduce entrainment mortality of salmonids in the south Delta, but would likely increase entrainment mortality at the intake of a peripheral aqueduct at Hood , where the abundance of salmonids tend to be higher because there are many more salmon in the Sacramento basin than near the SWP/CVP intakes (SLC 1). To the extent that water diversions would occur from the Sacramento River through a positive barrier fish screen there would be a substantial net benefit to salmonids. This benefit would be diminished by continued diversions from the south Delta. Also, as Delta conveyance towards the CVP/SWP pumps, salmonids may be swept with this water towards the pumps, thus increasing vulnerability to entrainment. Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing salmonid mortality. The reduction in mortality as a result of this bundle could be greater than Bundle #2 depending on how much of a reduction in water demand and Delta diversion exists, is similar to but likely lower than Bundle 5, and will likely fall somewhere in the middle of the other water operations and conveyance bundles.

A dual conveyance facility has great potential to increase water quality and flow conditions (SLC 2) in the planning area because there will be no need to have a hydrologic barrier to keep salinity low in the south Delta. Improvements in water quality will have similar impacts to the salmonid populations to those discussed in #2, but will likely be greater. Improvements will also be greater than constructing an IF alone (#5) because there will be improved water conveyance through the Delta.

The IF would likely greatly increase the quality and quantity of juvenile salmonid rearing habitat and migration corridors throughout the Delta (SLC 3; see 2.3.1.3). This effect on the overall salmonid population would likely be lower than that of the IF alone (#5) because reinforcements of levees and channel dredging will not provide salmonid habitat.

This bundle would likely moderately increase food quality, quantity, and accessibility (SLC 4), moderately reduce abundances of non-native competitors and predators (SLC 5), and moderately improve ecosystem processes for salmonids (SLC 6) for reasons discussed in #5. However, the magnitude of these impacts would be lower here than for #5 for this bundle.

Construction of the dual conveyance facility would be a very long process, although, because it is smaller than that in #5, it should take less time to construct (SLC 7). However, improving conveyance through the Delta will also take a long time. Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of salmonids.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.7.1.4 Splittail

Constructing and operating dual conveyance facilities would likely result in limited reductions on splittail mortality. It would likely reduce entrainment mortality of splittail in the south Delta, but would likely increase entrainment mortality at the intake of an isolated facility at Hood (SLC 1). Assuming similar abundances of splittail at both locations, there would be a net reduction in entrainment because the IF would have state of the art screening on the intakes. However, mortality at the export facilities is not great enough in most years to affect overall population abundance such that construction of the isolated facility will have only moderate reductions in splittail mortality. Also, as Delta conveyance towards the CVP/SWP pumps occurs in the through-delta channels, splittail may be swept with this water towards the pumps (e.g., reverse flows), thus increasing entrainment. Improving flow-related habitat conditions may reduce the abundance of non-native predators, thus reducing splittail mortality. The reduction in mortality as a result of this bundle could be greater than Bundle 2 depending on how much of a reduction in water demand and Delta diversion exists, is similar to but likely greater than Bundle 5, and will likely fall somewhere in the middle of the other water operations and conveyance bundles.

This bundle will likely cause a small increase water quality (e.g., lower temperature and higher DO) but a small decrease in flow conditions for splittail because through-Delta conveyance creates non-natural flows through the Delta (SLC 2) .

This bundle would likely moderately increase the amount of spawning habitat available to splittail from re-operation of upstream storage facilities and would allow for more natural hydrologic conditions that may support adult populations (SLC 3). However, because of non-natural through-Delta conveyance, there may be a negative effect on the quality of habitat in the interior Delta. Because the interior Delta is not preferred habitat by splittail, this effect would likely be minimal such that the overall effect on habitat would be moderately positive to splittail.

This bundle would likely moderately increase food quality, quantity, and accessibility (although a reduction in hydrologic residence time in the interior Delta will likely reduce productivity) (SLC 4), moderately reduce abundances of non-native competitors and predators (SLC 5), and moderately improve ecosystem processes for splittail (SLC 6) for reasons discussed in other water operations and conveyance bundles that reestablish fluctuating hydrologic conditions. However, the magnitude of these impacts would be lower for this water operations and conveyance bundle.

Construction of the isolated facility would likely be a very long process, although, because it is smaller than that in Bundle 5, it should take less time to construct (SLC 7). However, improving conveyance through the Delta will also take a long time. Therefore, this bundle is among the lowest in its ability to be implemented with in a time frame to meet the near-term needs of splittail.

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.7.2 Planning criteria (#8-#10)

Dual Conveyance Facilities have the potential to meet the water supply goals of the SWP and CVP PREs. Export levels could be maintained at current levels or even greater levels than present, while reducing take of covered species. This outcome is less likely for this bundle than the other bundles that include isolated facilities, because a larger percentage of the exports would still be diverted at the existing south Delta facilities. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

There are a number of unknowns related to the feasibility of Dual Conveyance Facilities. Among the most important feasibility issues are:

- Can an alignment for the aqueduct be found (some development has already occurred in the alignment for the original Peripheral Canal)?
- Is the construction of an isolated facility politically feasible?
- Can the through Delta conveyance facilities (improved levees) be constructed that would survive a large seismic event and ongoing subsidence?

Under CALFED's Preferred Program Alternative, two Delta conveyance facilities improvements included 1) evaluating and implementing improved operational procedures for the Delta Cross Channel to address fishery and water quality concerns; and 2) simultaneously evaluating a screened Through-Delta facility on the Sacramento River up to 4,000 cfs. Preliminary cost estimates for the Through-Delta facility cited by the Finance Options Report ranged between \$350 and \$500 million.[12] In 1997, CALFED developed preliminary facility descriptions and cost estimates for three alternative IF capacities: 15,000 cfs, 10,000 cfs, and 5,000 cfs.[13] The estimated capital cost for the 5,000 cfs IF was approximately 21% lower than the 10,000 cfs facility. The less than proportional change in cost relative to capacity is likely due to foregone economies of scale. Assuming this bundle entails a canal roughly half the size of Bundle #5, and applying the 21% cost reduction factor, the cost range for this element would be between \$1.6 and \$2.4 billion, exclusive of Delta ecosystem support, selected levee improvements and possibly some channel and levee modifications for water quality management. Operational elements of this bundle can be accomplished with existing facilities and therefore do not entail any significant additional capital costs.

This bundle would entail a very large capital expense. It would also involve elements (the Isolated Facility) that would be very controversial. Thus, the funding feasibility of this bundle would be relatively low, roughly equivalent to Bundles #3, 4, and 5.

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[12] CALFED Draft Finance Options Report, page 143.
[13] CALFED: *Facility Descriptions and Updated Cost Estimates*, Sacramento, California, October 1997.

2.7.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

This isolated facility and levee improvements components of this bundle would need to be designed with consideration of potential seismic loading and sea level rise. Unlike conveyance under Bundles #4-6, Bundle #7 requires levees to provide through Delta conveyance and these levees would be at risk for failures associated with sea level rise, subsidence, and other factors.

Construction and operation of dual conveyance facilities would reduce the need for manipulating Delta in-flow and through Delta channel flows to meet export requirements relative to CSAs 1, 2, and 8. During periods that through Delta conveyance facilities are not operating, flow-related ecosystem processes in these portions of the Delta could be restored to a more natural state. These benefits, however, are not expected to be as great as water operations and conveyance bundles that permanently isolate portions of the Delta from conveyance uses. Periodic ongoing human interventions would be required to maintain structural elements that support improvements to flow-related ecological processes. Because this bundle reduces the dependence on Delta channels for conveyance, a dual conveyance facility is expected to be more adaptable for meeting the needs of covered fish species than Bundles #1, 2, and 8.

Implementation of a dual conveyance facility configuration would represent an extremely large construction project, and would involve a large capital cost. It would be extremely difficult logistically and extremely costly to remove the aqueduct or stop using it once it was constructed. The construction would likely be funded through the issuance of bonds, which would need to be paid back regardless if a revenue stream from water sales was available. So, from a practical perspective, this bundle is considered to be highly irreversible.

2.7.4 Other Resource Impacts Criteria (#15-#17)

Construction and operation of dual conveyance facilities would likely have a positive effect on other native aquatic species inside and outside the planning area, as described for bundle #5, but likely to a lesser degree than under bundles #3-#6.

Construction of dual conveyance facilities could result in the physical loss of habitat for native riparian, wetland, and terrestrial species along the construction corridor of the peripheral aqueduct and at newly-constructed diversions and facilities. These impacts would be similar in magnitude to Bundle #5. Reinforcing levees and dredging channels to improve through Delta conveyance would result in losses of marsh and riparian vegetation and native plants and wildlife. Bundle #7 effects on habitat for riparian and terrestrial native species within the Delta would be greater than under Bundles #1-3.

The activities included in Bundle #6 would involve an extensive amount of construction, more than the other water operations and conveyance bundles because it involves both an isolated facility and a through-Delta component. This bundle would likely involve more aquatic impacts than other bundles involving isolated conveyance facilities, because of the large amount of in-water work that would likely be involved in improving levees for the through-Delta facility.

Impacts on the human environment would include all of the impacts identified under Bundle #5 and additional impacts on water quality and recreation in the area of through-Delta conveyance improvement.

2.8 BUNDLE #8: SAN JOAQUIN RIVER CORRIDOR ISOLATED FROM THROUGH-DELTA CONVEYANCE AND SWP/CVP INTAKES

Bundle 8 includes elements that involve the isolation of San Joaquin River flows from through-Delta conveyance and the SWP/CVP intakes:

- 8a. Divide the Old River channel to allow San Joaquin River flow to be separated from Victoria Canal water supply flows and install structures to regulate flows such that San Joaquin River flows are separated from the pumps and allowed to pass to the central Delta.
- 8b. Reconfigure in-Delta conveyance to create a water supply corridor toward the SWP and CVP using the DCC, rock barriers, floodgates, siphons, and pumps.
- 8c. Operate Split Delta conveyance facilities to provide transport flows for juvenile Delta smelt and improve salinity conditions for estuarine fish along the lower San Joaquin River to Franks Tract.

2.8.1 Biological Criteria (#1-#7)

2.8.1.1 Smelt (Delta and longfin)

Isolating San Joaquin River flows from a through-Delta conveyance facility has the potential to result in an increase in the vulnerability of Delta and longfin smelt to entrainment losses of the SWP and CVP export facilities. Through isolating the San Joaquin River export facilities would entrain a greater proportion of water from the central and southern Delta, which would be expected to increase the vulnerability of various life-history stages of smelt to entrainment loss when compared to existing baseline conditions (SLC 1).

Bifurcating the through-Delta facility from the lower San Joaquin River may contribute to a small incremental adverse impact on smelt. As noted in response to SLC #1, isolating the export facilities from the San Joaquin River would increase the hydraulic movement of water from the Sacramento River through the interior Delta and would be expected to increase channel velocities and the net flow through Old and Middle rivers. These changes in hydrodynamic conditions would be expected to adversely impact various life-history stages of smelt (SLC 2).

The effects of the through-Delta operations with isolation of the lower San Joaquin River on food availability and nutrient loading within the Delta are unknown. Operation of the through-Delta facility would increase channel velocities and reduce hydraulic residence time as water passes from the Sacramento River through the Delta to the south Delta export facilities. These hydraulic conditions would be similar or worse than those that occur under existing baseline conditions. In contrast, isolation of flow of the lower San Joaquin River would allow greater nutrient loading from the San Joaquin River watershed into the Delta that may increase primary and secondary production, particularly within the central and western Delta and Suisun Marsh and bay. The relative magnitude and balance between these competing processes under the proposed bundle on primary and secondary production have a high degree of uncertainty (SLC 3).

The proposed through-Delta conveyance facility would be expected to increase channel velocities and reduce hydraulic residence time and thereby contribute to an incremental reduction in ecosystem processes. The isolation of the lower San Joaquin River would allow for a generally west net flow of the San Joaquin River and result in localized improvements to hydrologic conditions within the central portion of the Delta associated with the lower San Joaquin River channel. Improvements in the hydraulic conditions of the lower San Joaquin River would be expected to improve ecosystem processes on a localized scale, but would not result in a net overall improvement in ecological processes within the Delta affecting smelt (SLC 6).

Increasing the channel capacity and levee armoring for an increased through Delta facility conveyance while constructing the necessary gates and control structures to isolate the San Joaquin River would be expected to take less time for implementation when compared to isolated facilities described in Bundles #5, 6, and 7. Implementation of the bundle would be expected to take years or a decade or more (SLC 7).

2.8.1.2 Sturgeon (green and white)

Isolating San Joaquin River flows from SWP/ CVP pumping facilities and reconfigured through-Delta conveyance system would have an unknown effect on sturgeon non-natural mortality (SLC 1). Under the assumption that the isolation of San Joaquin River flows from the SWP/CVP pumps would cause water to be drawn from other regions of the Delta, this bundle has the potential to increase sturgeon entrainment.

This bundle would increase flows through the delta channels and thereby increase water velocities and reduce residence times. These changes would be expected to reduce habitat quality for sturgeon and reduce food production within the Delta.

Constructing and installing the necessary structures required to isolate San Joaquin River flows from the SWP/CVP pumping facilities and through-Delta conveyance would result in slow implementation of this bundle (SLC 7), and

The cumulative impact of the action on the sturgeon population is not known. Based on the available information, the certainty of the assessment of this bundle is very low.

2.8.1.3 Salmonids

This bundle would likely minimally reduce non-natural mortality of salmonids (SLC 1). Entrainment mortality of San Joaquin River salmonids at the CVP/SWP intakes would be substantially reduced because these fish would be isolated from the water supply corridor until they reach the central Delta. It could, however, entrain salmonids from the Sacramento River entering the water supply corridor, despite the sophistication of the fish barrier to be installed at the DCC and Georgiana Slough. Additionally, there are more fish passing through the Sacramento River than in the area of the SWP/CVP facilities, resulting in higher entrainment. Overall, this action will likely not positively impact the salmonid population in terms of reducing mortality. This bundle is expected to improve conditions for salmonids emigrating from the San Joaquin River system.

This bundle would likely do little to improve water quality for salmonids (SLC 2). Water quality in the south Delta would likely improve because San Joaquin River water would not be entering this area (SLC 2), but would likely decrease in the central and west Delta and into the estuary (where sexually immature adults tend to concentrate) because this San Joaquin River water (and all its particulates) will not have had a chance to mix with other water sources and dilute as they move downstream. Flow conditions will improve conditions for salmonids coming from the San Joaquin River although this effect on the overall population will likely be low due to the disparity between San Joaquin and Sacramento River numbers of salmonids.

Because San Joaquin River water will be channeled directly towards the central Delta, there is a potential for this nutrient-rich water to improve food abundance for salmonids rearing in the estuary downstream as a result of implementation of this bundle (SLC 3). Therefore, this would provide a minimally positive improvement to the overall salmonid population.

Due to the large amount of reconfiguration and construction of barriers for corridors, this water operations and conveyance bundle will likely require more time than Bundles 1-3, but less than 3-7. Therefore, it has moderate potential for being implemented within a timeframe to meet near-term needs of salmonids (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.8.1.4 Splittail

This bundle would likely minimally reduce, and may increase, non-natural mortality of splittail (SLC 1). Entrainment mortality of San Joaquin River splittail at the CVP/SWP intakes would likely be reduced because these fish would be isolated from the water supply corridor until they reach the central Delta. It could, however, entrain splittail from the Sacramento River entering the water supply corridor, despite the sophistication of the fish barrier to be installed at the DCC and Georgiana Slough. In addition, exposure to toxics of splittail will increase if water containing toxics from the San Joaquin River is channeled farther downstream without the chance to mix with other water sources upstream and dilute before it gets to the estuary (where immature adults tend to concentrate). Exposure to toxics was a top stressor identified in Technical Workgroup meetings.

This bundle would likely do little to improve water quality and flow conditions for splittail (SLC 2). The increase in flows through Delta channels would be expected to reduce habitat conditions and food production. Water quality in the south Delta would likely improve because San Joaquin River water would not be entering this area (SLC 2), but would likely decrease in the central and west Delta and into the estuary (where immature adults tend to concentrate) because this San Joaquin River water (and all its particulates) will not have had a chance to mix with other water sources and dilute as they move downstream. Flow conditions will not improve in a way to increase splittail abundance, distribution, or production.

Because San Joaquin River water will be channeled directly towards the central Delta, there is a potential for this nutrient-rich water to improve food abundance for splittail downstream (e.g., Suisun Bay and Marsh) as a result of implementation of this Bundle (SLC 4). More food allows for greater growth and larger and healthier fish. Therefore, this bundle would likely allow for moderately positive impacts on the splittail population.

Due to the large amount of reconfiguration and construction of barriers for corridors, this bundle will likely require more time than Bundles 1-3, but less than 4-7. Therefore, it has moderate potential for being implemented within a timeframe to meet near-term needs of splittail (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, other than assessment of SLC 5.

2.8.2 Planning Criteria (#8-#10)

Bundle #8 has the potential to meet the water supply goals of the CVP and SWP PREs. Export levels could be maintained at current levels or even greater levels than present, while reducing take of covered species. This bundle would not affect operations of Mirant's Delta plants and therefore doesn't apply to their goals.

Bundle #8 involves commonly used structures (fish screens, pumps, siphons, walls) and appears to be feasible from an engineering perspective.

This bundle entails construction of the South Delta Improvement Program operable gates as well as several other additional structures. Additional structures include four rock barriers with boat locks; a large box-culvert siphon with a capacity of 15,000 cfs; a flood-gate located downstream of the Head of Old River; a wall between Grant Line Canal and Coney Island opposite the CCFB intake to separate the San Joaquin River flowing north from the West Canal water supply flowing to the CCFB and the Delta Mendota Canal intake; a flood-gate and boat lock to block the north end of West Canal from the downstream portion of Old River; relocation of both CCWD intakes to the Middle River corridor; two 2,000-feet long fish screens to separate Sacramento fish from the DCC and Georgiana Slough flows to the Mokelumne and San Joaquin River channels. The fish screens would be similar to the Glenn-Colusa Irrigation District (GCID) screen, but would include a 5-feet high concrete panel at the bottom and a 10-feet high concrete panel at the top.[14]

SDIP operable gates and related actions are expected to have capital costs in the range of $110 million and annual operating costs of about $1 million/year. The Glenn-Colusa Irrigation District (GCID) fish screen project had a $76 million capital cost.[15] The project constructed a 620-feet extension to the existing interim GCID fish screen, an average cost of about $12.3 million per 100-feet of screen. Applying this average unit cost to the two proposed fish screens suggests that screening costs for Bundle #8 may be on the order of $500 million. CCWD's Alternative Intake Project has an estimated planning and construction cost of $100 million.[16] Relocation of both CCWD intakes may therefore cost on the order of $200 million. CALFED's 1997 analysis of isolated facility configurations and costs estimated that a 15,000 cfs siphon under the San Joaquin River would cost about $80 million (updated to 2006 dollars). We are unaware of cost estimates for the four rock barriers with boat locks, the wall between Grant Line Canal and Coney Island, and the flood-gate and boat lock. We assume total costs for these items would be similar in magnitude to SDIP, about $100 million. The above construction cost estimates add to approximately $1 billion. Accounting for the high degree of uncertainty of these estimates, and recognizing the higher likelihood of understating rather than overstating

[14] The description of structures required to implement bundle #8 is drawn from Jones & Stokes: *Proposal to Reconnect the San Joaquin River to the Estuary*, March 23, 2007.
[15] http://www.gcid.net/documents/gcid%20brochure%20pdfs/Fish_protection.pdf
[16] http://www.ccwater-alternativeintake.com/pdfs/AIP%20fact%20sheet.pdf

costs, capital costs for this bundle may range between $.75 and $1.75 billion. Operational costs for are unknown.

This bundle would entail a very large capital expense (hundreds of millions to billions of dollars). It would also involve elements (massive changes to Delta channel configurations) that would likely be controversial, though probably less so than an isolated facility. Thus, the funding feasibility of this bundle would be moderate, more than Bundles #1 and 2, but less than Bundles #3-7).

2.8.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

All new structures and channel modifications associated with this bundle would need to be designed with consideration of potential seismic loading and sea level rise. The levees along the west side of Middle River would be subject to failure unless hardened. The conveyance also depends on maintaining levee integrity of islands east of middle river. Island failure, however, could be tolerated along the old river corridor (the new outlet of the San Joaquin).

Isolation of San Joaquin River flows from the CVP/SWP pumping facilities would eliminate the need for manipulating San Joaquin River flows to meet export requirements in the south Delta and thus are expected to improve the flow-related ecosystem processes supported by San Joaquin River flows. This bundle would improve ecosystem processes in the lower San Joaquin River to a greater degree than Bundles #1-4 and 6, but would not improve flow-related ecological processes elsewhere in the Delta. Periodic ongoing human interventions to maintain structures that isolate San Joaquin River flows would be required maintain improvements to San Joaquin River flow-related processes. This bundle is likely the least adaptable among the water operations and conveyance bundles because the bundle components would need to work in concert, and, therefore unlikely to be flexible or readily manipulable.

Bundle #8 would involve a considerable amount of construction (two very large fish screens, a very large siphon, several thousand feet of dividing walls in south Delta channels, relocation of an intake structure, and construction of several rock barriers and pumps. Undoing these changes would likely be difficult, but more reversible than bundles involving an isolated facility or new storage and conveyance (Bundles #3-7).

2.8.4 Other Resource Impacts Criteria (#15-#17)

Isolation of San Joaquin River flows from the CVP/SWP pumping facilities would likely improve habitat conditions for native aquatic species along the San Joaquin River because San Joaquin River flows would be restored to the south Delta. The degree of this benefit to other native species is likely less than benefits that may be provided under Bundles #3-#6 because the extent of affected channels is limited to the San Joaquin River corridor. Bundle #8 would not likely affect other native species outside of the BDCP planning area

Construction of facilities to isolate the San Joaquin River could result in the physical loss of habitat for native riparian and terrestrial species within the BDCP planning area, but losses would likely be minor and localized. Consequently, this bundle is expected to have fewer impacts associated with loss of habitat for native species than under Bundles #4-7.

The activities included in Bundle #8 would involve an extensive amount of construction and associated impacts to the human environment. Though probably significant, Bundle #8 adverse effects would be less than Bundles #3-7, which involve more construction. It is unknown what effect Bundle #8 would have on Delta agriculture. If it improved water quality in the south Delta, that could result in improved agricultural productivity in that area.

3.0 ENTRAINMENT AND PREDATION MORTALITY REDUCTION BUNDLES

3.1 BUNDLE #9: MINIMIZE FISH MORTALITY ASSOCIATED WITH ENTRAINMENT AT SWP/CVP INTAKES

Bundle 9 includes elements that involve minimizing fish mortality associated with entrainment at the SWP/CVP diversions:

- 9a. Improvements to louver facilities at SWP and CVP pumps to minimize fish mortality
- 9b. Improve the SWP/CVP salvage collection, handling, transportation, and release (CHTR) processes to increase survival
- 9c. Improve facilities and pumping operations to minimize passage of fish into Clifton Court Forebay (CCF)
- 9d. Modify in-channel habitat structure at SWP/CVP facilities to reduce conditions that support predation of native fishes

3.1.1 Biological Criteria (#1-#7)

3.1.1.1 Smelt (Delta and longfin)

Delta smelt and longfin smelt are extremely sensitive to collection, handling, transport, and release from the SWP and CVP salvage facilities. Although some small incremental improvements in survival of salvage Delta smelt may be possible, the incremental effects of these changes on improving Delta smelt survival are expected to be very small (SLC 1). Improvements in salvage handling and increases in survival would be expected to reduce the mortality to non-native species and thereby contribute to potential increases, rather than decreases, in the abundance of non-native fish species (SLC 5).

Investigations are currently underway to identify methods for improving salvage survival. Identification of management actions and implementation could be accomplished within a period of years (SLC 7).

3.1.1.2 Sturgeon (green and white)

Improving and modifying the fish salvage facilities of the SWP/CVP to minimize entrainment could reduce sturgeon non-natural mortality dependant upon the cumulative changes that are implemented but the impact to sturgeon on the population level is not known (SLC 1). While it is known that sturgeon are present in Clifton Court Forebay, relatively little information exists on how they are impacted by salvage/pumping operations.

Modifying and installing the necessary structures required to minimize the entrainment of sturgeon at the SWP/CVP export facilities and improve fish salvage operations would require a moderate timeframe to see benefits (SLC 7).

The cumulative impact of this action on sturgeon is not known. Based on the available information, the certainty of the assessment of this bundle is very low.

3.1.2.3 Salmonids

Improvements to existing SWP/CVP intakes will likely have a moderate positive effect on salmonids, particularly if improvements are made to reduce mortality of salmonids by striped bass predation in CCF (SLC 1). Because entrainment is low relative to the population of most salmonid ESUs, this bundle will likely have minimal effects to these ESUs. However, these effects will likely be more beneficial to late fall-, spring, and winter-run Chinook.

Improvement to the fish salvage facilities will likely reduce mortality of non-native predators (and competitors, although they are likely not a strong stressor) of salmonids also, thus having an indirect negative effect on salmonids (SLC 5). The magnitude of this indirect effect would be directly proportional to the vulnerability of the non-native species to entrainment and the strength of the relationship between the non-native species and salmonids (=effect of the non-native on salmonids). Non-native predation is a moderately important stressor to salmonids. Thus, the effect of this action on salmonids will be moderately negative.

Some elements of this This bundle will likely take a long time implement because of the number of physical improvements to the facilities such as modification to CCF. Therefore, this bundle may be difficult to implement within a timeframe that meets the near term needs of salmonids relative to other bundles. Many of the other improvements, such as development of additional release sites, purchase of new transport trucks, etc. could be implemented quickly (within a year) (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high.

3.1.2.4 Splittail

Improvements to existing SWP/CVP intakes will reduce mortality of splittail, but the effect will be only moderate on splittail at a population level during most years because entrainment at the pumps is not generally a major stressor for splittail (SLC 1).

Improvement to the salvage facilities will likely reduce mortality of non-native predators (and competitors, although they are likely not a strong stressor) of splittail, thus having an indirect negative effect on splittail (SLC 5). The magnitude of this indirect effect would be directly proportional to the vulnerability of the non-native species to entrainment and the strength of the relationship between the non-native species and splittail (=effect of the non-native on splittail). Although non-native predation is widespread geographically (according to Technical Workgroup Meetings), the severity of the impact on splittail is unknown but is likely relatively low. Therefore, because the SWP/CVP intakes are in one place, the effect of this problem on the overall splittail population is likely to be minimally negative to splittail.

This mortality reduction bundle will likely take a long time because of the number of physical improvements to the facilities. Modification of Clifton Court Forebay would require time for design and construction. Other aspects of this element, such as modification to the handling procedures, development of additional release sites, purchase of additional transport trucks, etc. could be implemented immediately.

Based on the available information, the certainty of the assessment of this bundle is considered high.

3.1.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. All of the activities in Bundle #9 have been studied for many years and are generally considered feasible from an engineering standpoint. These activities might include repairing or replacing the louver screens to increase louver efficiencies; replacing the fleet of trucks used to transport fish collected at the intake structures and changing how they are released into the Delta following harvest; and reducing fish mortality in CCF caused by predation by filling scour holes and making other modifications to the interior of CCF. Capital costs to undertake these improvements are expected to be on the order of $5 to $10 million. Some of the actions under Bundle #9 may entail altering the level and timing of pumping by the SWP/CVP in ways that would increase O&M costs. For example, less pumping during off-peak power periods may be required under this bundle. Similarly, changing the operation of the radial gate at the entrance of CCF may require more pumping when CCF water levels are low, which may require reduced pumping rates to prevent pump cavitation. To our knowledge cost studies of these actions have yet to be undertaken and we therefore attach a low degree of confidence to this cost estimate.

The likely relatively low cost of these actions, the fact that they would be able to be funded incrementally, and the fact that some of the actions are relatively easily reversible, gives this bundle a relatively high funding feasibility.

3.1.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

All new facilities and improvements would need to be designed with consideration of potential seismic loading and sea level rise.

This bundle does not restore ecosystem processes that support species, but rather removes sources of direct mortality. To the extent that specific mortality reduction measures can continually be tested and improved, this bundle is moderately adaptable. The degree to which mortality-reduction practices can be improved and practicability of implementation are not well known. Mortality-reduction measures could be implemented early and could be adapted to constitute a portion of any conservation strategy developed.

Bundle #9 would involve a moderate amount of construction and, with the exception of changes to the louvers at the CVP and SWP diversion facilities, bundle elements would be relatively easy to reverse.

3.1.4 Other Resource Impacts Criteria (#15-#17)

Implementation of measures to reduce entrainment at CVP/SWP diversions is expected to be beneficial for other native aquatic species within the BDCP planning area because entrainment-associated mortality of these species would be reduced. Bundle #9 is expected to provide greater benefits for native aquatic species than Bundles #10 and #11. It would not likely have effects outside the planning area.

Bundle #9 could involve moderate amounts of construction and associated negative affects impacts to the human environment. It would not result in changes to water supply or quality to Delta farmers, nor convert any existing agricultural lands to other uses, so its socio-economic effects would likely be small.

3.2 BUNDLE #10: MINIMIZE ENTRAINMENT AT NON-SWP/CVP DIVERSIONS

Bundle 10 includes elements that involve minimizing entrainment at non-SWP/CVP diversions:

- 10a. Removal and consolidation of in-Delta diversions to minimize entrainment losses of fish
- 10b. Improve the effectiveness of ineffective screened diversions within the Delta
- 10c. Screen un-screened in-Delta diversions

3.2.1 Biological Criteria (#1-#7)

3.2.1.1 Smelt (Delta and longfin)

Although there are a large number of currently unscreened water diversions located throughout the Delta, the effects of these diversion operations on mortality of various life-history stages of smelt are largely unknown. Larval smelt are expected to be vulnerable to entrainment during the spring at these unscreened diversions however the available data suggests that juvenile and adult smelt would be able to avoid diversion losses. The biological benefit of reduced diversions from the Delta would vary depending on the specific location where the diversion reductions occur, the seasonal time periods when diversion operations would occur, and the magnitude of the reduction in diversion operations. Reductions in diversions during the late winter and early spring months would have the greatest potential for reducing entrainment losses of larval smelt, while reductions in diversions throughout the remainder of the year would be expected to have relatively little or no effect on reducing diversion-related mortality for smelt (SLC 1).

Reduction in diversion operations would result in localized and cumulative changes in Delta hydrodynamic conditions and associated water quality (e.g., salinity intrusion) that would potentially benefit various life-history stages of smelt. The magnitude of these potential benefits of altered hydrologic conditions as a result diversion reductions would vary depending on the magnitude of the diversion reduction, the location, and the seasonal timing (SLC 2). Reduction in Delta diversions would not directly affect physical habitat quality or availability, but would provide an incremental benefit to habitat conditions through altered local hydrology. Reductions in Delta diversions would be expected to contribute to localized increases in hydraulic residence time that would benefit localized habitat for smelt. As noted above, the magnitude of these potential biological benefits would vary in response to the magnitude and seasonal timing of diversion reductions (SLC 3).

Reducing diversions from the Delta would be expected to result in a direct benefit to quality and availability of food supplies and potentially nutrients. Phytoplankton and zooplankton are diverted from the Delta at the large number of diversion locations and are removed from the Delta aquatic ecosystem. Although diversions from each of these individual locations is relatively small, the large number of diversions and their broad geographic distribution within the Delta increases their potential effect on food supplies and also the potential incremental biological benefit that may occur as a result of reduced diversion operations. The magnitude of these potential benefits would vary based on the location, seasonal timing, and magnitude of diversion reductions. In contrast, reductions in Delta diversion operations would be expected to also result in a reduction in localized agricultural return flows that in many cases are characterized by relatively high concentrations of organic material and nutrients. These agricultural return flows support, in part, primary production by phytoplankton within the Delta. A reduction in agricultural return flows would also potentially benefit smelt on a localized basis since these discharge points frequently are characterized by depressed dissolved oxygen concentrations and, in a number of instances, serve as localized points of predator accumulations. Given these various factors, the overall net incremental change that would occur within the Delta trophic system as a result of reductions in diversion operations is unknown (SLC 4).

Diversion operations are expected to result in entrainment vulnerability of the early life-history stages of non-native species. Reductions in diversion operations would be expected to contribute to an overall increase, rather than a decrease, in the survival and potential population abundance of non-native species (SLC 5). Reductions in Delta diversions would be expected to contribute to a relatively small incremental change in ecosystem processes primarily through changes in localized hydraulics and residence time, as well as changes in the balance between primary and secondary production, nutrient loading, and diversion losses of lower trophic levels. Although the overall cumulative effects of reduced diversion operations is expected to be small on ecosystem processes, there is a high degree of uncertainty in the net biological response to the proposed changes (SLC 6).

Large-scale changes in Delta diversions would require coordinated operations and various institutional and land-use changes. Although the actual response of diversion operations could be implemented relatively fast at the time required to successfully coordinate these operations and implement institutional changes would be expected to take a decade or longer (SLC 7).

3.2.1.2 Sturgeon (green and white)

Screening, improving, removing, and consolidating in Delta diversions would likely have a low level impact on the sturgeon population (SLC 1). Diversions generally have their intakes off the bottom, while juvenile sturgeon in the Delta nursery areas, are known to hug the substrate. The highest chance of entrainment is to the down migrant juveniles during the summer. Although screening will reduce entrainment, the positive effects on sturgeon abundance would be marginal.

Screening, improving, removing, and consolidating in-Delta diversions could likely be accomplished in a moderate timeframe (SLC 7). This bundle would likely have a low impact on sturgeon at the population level. Based on the available information, the certainty of the assessment of this bundle is moderate.

3.2.1.3 Salmonids

Improvements to the approximately 1,800 or so non-SWP/CVP diversions located within the lower rivers and Delta have a small potential to reduce mortality of salmonids. Results of studies have shown that larger fish, such as juvenile Chinook salmon and steelhead have a low vulnerability to entertainment at these sites. Therefore, reductions in diversion rates would not be expected to contribute substantially to reduced mortality. (SLC 1).

Improvements to non-SWP/CVP diversions will likely reduce mortality of non-native predators (and competitors, although they are likely not a strong stressor) of salmonids, thus having an indirect negative effect on salmonids (SLC 5). The magnitude of this indirect effect would be directly proportional to the vulnerability of the non-native species (primarily eggs, larvae, and early juvenile life stages) to entrainment and the strength of the relationship between the non-native species and salmonids (=effect of the non-natives on salmonids). Therefore, this effect on the overall salmonids population is likely to be minimally negative.

Improvements to non-SWP/CVP diversions will likely take a long time because of the number of diversions that exist (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high.

3.2.1.4 Splittail

Improvements to the 1800 or so non-SWP/CVP diversions should reduce mortality of juvenile splittail depending on their location, but the effect will be only moderate to splittail on a population level during most years because entrainment at the pumps is not generally a major stressor for splittail (SLC 1).

Improvements to non-SWP/CVP diversions will likely reduce mortality of non-native predators (and competitors, although they are likely not a strong stressor) of splittail, thus having an indirect negative effect on splittail (SLC 5). The magnitude of this indirect effect would be directly proportional to the vulnerability of the non-native species (primarily eggs, larvae, and early juvenile life stages) to entrainment and the strength of the relationship between the non-native species and splittail (=effect of the non-natives on splittail). Therefore, this effect on the overall splittail population is likely to be minimally negative.

Improvements to non-SWP/CVP diversions will likely take a long time because of the number of diversions that exist (SLC 7).

3.2.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. Fish screening technology, particularly on smaller diversions is a well established technology and is very feasible. Successful implementation of this bundle will require the voluntary participation of non-BDCP entities that operate the diversions (e.g. Delta landowners). The willingness of Delta landowners and water districts to participate is unknown, and therefore the extent to which these diversions could be screened is unknown.

Costs to install and operate positive-barrier fish screens on un-screened in-Delta diversions will vary by number of un-screened diversion points, size of diversion, and geographic location. Costs can be highly specific to individual projects. CALFED analyzed costs to implement 42 fish screen projects funded through the ERP grant program. Construction costs totaled approximately $42 million. Costs for individual screening projects ranged between $15,000 and $6.0 million. Many of the screening projects were located outside the Delta. The CALFED Draft Finance Options Report (Finance Options Report) utilized an average cost of $1 million per fish screen project to estimate the cost of screening un-screened diversions located within the Delta and along its tributaries. Using data on Central Valley diversions from the CVPIA EIS/EIR, the Finance Options Report estimated there were between 89 and 133 unscreened diversions. The report did not provide information on the geographic location of these diversions and therefore it is not know how many are in-Delta. Assuming 1/4 to 1/2 of estimated un-screened diversions are in-Delta, screening costs for bundle #10 may be in the range of $20 to $70 million.

Because the assumed number of un-screened in-Delta diversions is highly speculative, a low degree of confidence should be given to this cost estimate.

The relatively low cost of this bundle, the fact that they could be funded incrementally, and the fact that they are relatively easily reversible, gives this bundle a relatively high funding feasibility.

3.2.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Possible effects of sea level rise and seismic events on this bundle are considered minimal except that any consolidated diversions would need to be designed with consideration of potential seismic loading and sea level rise.

This bundle does not restore ecosystem processes that support species, but rather removes sources of direct mortality. The likely adaptability of this bundle is limited to the extent that it is unlikely that future improvements in minimizing entrainment associated would be required with implementation of this bundle. Bundle #10 would likely be easily reversed. Fish screens can be easily removed from small diversions, though less easily in larger diversions (e.g. Mirant's). The consolidation of diversions would be more difficult to undo, but there would probably be no reason to undo them, as long as the water could continue to be diverted with the new facilities even without the screens.

3.2.4 Other Resource Impacts Criteria (#15-#17)

Implementation of measures to reduce entrainment at non-CVP/SWP diversions is expected to be beneficial for other native aquatic species within the BDCP planning area because entrainment-associated mortality of these species would be reduced, and little impact outside the planning area. Bundle #10 is expected to provide fewer benefits for native aquatic species than #9 because these diversions are small relative to the CVP/SWP facilities.

Construction activities and associated impacts on the human environment from Bundle #10 would be relatively small and short-term. Socio-economic effects would also be relatively small.

3.3 BUNDLE #11: IMPROVE HABITAT CONDITIONS IN DELTA LOCATIONS WHERE COVERED FISHES ARE HIGHLY VULNERABLE TO PREDATION TO CREATE HABITAT CONDITIONS THAT WILL REDUCE PREDATION LEVELS

Bundle 11 involves improving habitat conditions in delta locations where covered fishes are highly vulnerable to predation to create habitat conditions that will reduce predation levels.

3.3.1 Biological Criteria (#1-#7)

3.3.1.1 Smelt (Delta and longfin)

Delta smelt are vulnerable to predation mortality by striped bass, largemouth bass, Sacramento pikeminnow, and other fish species. Although specific information on localized points of increased vulnerability to predation for smelt are unknown, and it is speculated that common predator ambush points such as levee breaches on flooded islands, boat docks and piers, the return location from the SWP and CVP fish salvage operations, as well as areas within the Delta that have been colonized by submerged aquatic vegetation such as Brazilian waterweed (*Egeria densa*.) Given the high degree of uncertainty with respect to increased vulnerability of smelt at these specific locations it is difficult to predict the potential magnitude of a reduction in predation mortality as a function of removal of all or most of these potential ambush points. Since Delta self also spent a substantial proportion of their life as pelagic species, removal of specific ambush points would not eliminate predation mortality by pelagic species such as striped bass. As a result of the large number and wide geographic distribution of potential predation sites, it is expected that removal or reduction of a proportion of the sites would contribute to only a small incremental improvement in survival of Delta and longfin smelt (SLC 1).

Removal of predator ambush points may have a small incremental effect on a reduction in habitat quality for non-native predatory fish species, however this effect on population abundance is expected to be minimal. A substantial alternative habitat exists within the Delta that would potentially be occupied by fish displaced as a result of localized habitat improvements (SLC 5).

Modifications to predator ambush locations could be implemented within a period years (SLC 7).

3.3.1.2 Sturgeon (green and white)

Improving habitat conditions to reduce predation on sturgeon could reduce non-natural mortality by decreasing predator abundance (SLC 5). It is unknown to what degree this bundle would benefit sturgeon population abundance. Based on the available information, the certainty of the assessment of this bundle is low.

3.3.1.3 Salmonids

Improving habitat conditions to reduce predation in vulnerable places will likely reduce mortality of salmonids (SLC 1). The effect of this bundle on the overall salmonid populations will be moderate and primarily depend on how much of this habitat exists and is able to be improved in the Delta.

By reducing the number of deep pools, levee breaches on flooded islands, and other structures in the Delta, this bundle may minimally increase the quantity or quality of salmonid habitat (SLC 3).

The length of time required to improve habitat conditions will depend on both the amount of habitat available for improvement and the extent to which the habitat must be improved. As a result, it is difficult to determine the ability of this bundle to be implemented within a timeframe that meets the near term needs of salmonids (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.3.1.4 Splittail

Improving habitat conditions to reduce predation in vulnerable places will likely reduce mortality on splittail (SLC 1). Non-natural predation was identified in technical working sessions as one of the top stressors on splittail (SLC 5). By removing locations where non-native predators dwell, this bundle will reduce predation by non-natives. The effect of this bundle on the overall splittail population will be moderate and primarily depend on how much of this habitat exists and is able to be improved in the Delta.

By reducing the number of deep pools in the Delta, there should be increased shallow habitat (SLC 3). Therefore, this bundle may minimally increase the quantity of splittail habitat (Bundle #4).

The length of time required to improve habitat conditions will depend on both the amount of habitat available for improvement and the extent to which the habitat must be improved (depth of the pool). As a result, it is difficult to determine the ability of this bundle to be implemented within a timeframe that meets the near term needs of splittail (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.3.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. This bundle would likely involve relatively straightforward changes to aquatic habitats in specific locations. It is not expected that these changes would be particularly difficult from an engineering or cost perspective. To the extent that they occur on lands owned by others, it would be necessary for the owners of the land to participate voluntarily in order for the project to be implemented.

Costs for Bundle #11 will vary by type, extent, and location of physical habitat restoration projects. The CALFED Draft Finance Options Report evaluated costs for ERP projects funded by grants between 1997 and 2001. This analysis estimated cost ranges for Delta habitat acquisition, terrestrial/marsh habitat restoration, and instream habitat restoration, as shown in the following table. These unit costs could be coupled with in-Delta habitat acquisition and restoration levels as they become available to generate preliminary cost ranges for alternative levels of restoration.

Range	Land Acquisition ($/Ac)	Terrestrial Restoration ($/Ac)	Instream Restoration ($/Mi)
Low	$3,100	$500	$70,000
High	$3,700	$2,000	$280,000

The relatively low cost of these actions, the fact that they could be funded incrementally, and the fact that they are relatively easily reversible, gives this bundle a relatively high funding feasibility.

3.3.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Potential effects of sea level rise, seismic events, climate change, and levee failures could include loss or alteration of the habitat, but the magnitude of these effects would likely be minimal. For example, if in-channel structures are removed to remove non-native predator habitat, then it is unlikely that the benefit of the action would be affected.

This bundle does not restore ecosystem processes that support species, but rather removes sources of direct mortality. Habitat restoration measures for predation-reduction would be expected to be highly adaptable in both scale and geographic distribution. They would include site specific actions that could be monitored for efficacy and practicability, in order to improve methods over time. Actions implemented under Bundle #11 would be fairly easily reversed, though it is unlikely that this would need to be undertaken, unless they failed to work as designed.

3.3.4 Other Resource Impacts Criteria (#15-#17)

Implementation of measures to reduce predation levels would be beneficial for other native aquatic species within the BDCP planning area because levels of non-native predation on native aquatic species would be reduced. It would not significantly affect other species outside the planning area. Bundle #11 is expected to provide fewer benefits for native aquatic species than Bundle #9.

The activities involved in Bundle #11 would involve some construction to modify habitats so as to reduce predation impacts, but impacts to the human environment would be temporary and localized. Socio-economic effects would only occur if the habitat improvements involved the removal of some land from agricultural or other income-producing uses to habitat purposes.

3.4 BUNDLE #12: ISOLATION OF CAPTURED GRAVEL PITS UPSTREAM OF DELTA

Bundle 12 involves the isolation of captured gravel pits upstream of Delta to reduce the mortality of salmonids and splittail.

3.4.1 Biological Criteria (#1-#7)

3.4.1.1 Smelt (Delta and longfin)

Isolation of gravel pits upstream of the delta is expected to have negligible to no effects on smelt.

3.4.1.2 Sturgeon (green and white)

Isolation of captured gravel pits upstream of the Delta will have very little effect on green or white sturgeon. The effects of this bundle on the SLC's in regard to sturgeon are minimal at best. Ongoing sampling on the Feather River in captured gravel pits indicates that this is not a problem for these species. Therefore, the effect of this action is expected to be very low. Based on the available information, the certainty of the assessment of this bundle is considered high.

3.4.1.3 Salmonids

Isolating captured gravel pits will reduce mortality of salmonids (SLC 1). Juvenile salmonids may get entrained in gravel pits as they are migrating downstream. Gravel pits, because they are deep, are similar to deep pools discussed in 3.3.1.3 in terms of their ability to attract non-native predatory fish. By removing locations where non-native predators dwell, this bundle will reduce predation by non-natives. This action would have the greatest benefit to salmonids produced on San Joaquin River tributaries where the majority of gravel pits exist. Therefore, this bundle will have smaller impacts than other bundles on salmonids at a population level.

If gravel pits were restored to elevations to provide channel habitats rather than isolated from the river, increased habitat for salmonids could result (SLC 3). However, the effect of this action on the overall salmonid population would likely be minimal.

The length of time required to improve habitat conditions will depend on both the amount of gravel pit habitat and the extent of the isolation. As a result, it is difficult to determine the ability of this this bundle to be implemented within a timeframe that meets the near term needs of salmonids (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.4.1.4 Splittail

Isolating captured gravel pits will likely reduce mortality of splittail (SLC 1). Juvenile splittail may get entrained in gravel pits as they are migrating downstream to rear. Gravel pits, because they are deep, are similar to deep pools discussed in 3.3.1.4 in terms of their ability to attract non-native predatory fish. Non-natural predation was identified in Technical Workgroup meetings as one of the top stressors on splittail (SLC 5). By removing locations where non-native predators dwell, this bundle will reduce predation by non-natives. However, because these gravel pits are upstream, a proportion of them may be upstream of some splittail spawning habitat. Therefore, this bundle will have smaller impacts than other mortality reduction bundles on splittail at a population level.

The length of time required to improve habitat conditions will depend on both the amount of gravel pit habitat and the extent to which the habitat must be improved (depth or size of the gravel pit). As a result, it is difficult to determine the ability of this bundle to be implemented within a timeframe that meets the near term needs of splittail (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.4.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The isolation of captured gravel pits (principally in the San Joaquin River and its tributaries) has been studied for many years. There are many acres of captured gravel pits, and some are very deep. Solving this problem is very challenging from an engineering perspective, not only because of the size of the problem, but because of the need for any fix to withstand the large water forces that occur within rivers. This bundle is the least feasible of the Predation and Other Mortality Reduction Bundles. In addition, voluntary landowner participation would be required if construction required land currently in private ownership.

Costs for Bundle #12 will vary by type, extent, and location of gravel pit restoration projects. Costs of two prior gravel pit restoration projects are presented as indicators of the possible range of cost per project.

ERP-97-M09 involved filling mining pits and constructing setback levees for 6.1 miles along off-stream gravel mining reaches on the Tuolumne River below La Grange Dam, to remove predator habitat and encourage a more natural dynamic riverine morphology and habitat.

Tasks included: Project designs, permits, civil engineering, construction, and revegetation. The project budget was $7.2 million.

ERP-97-M08 involved rebuilding a select portion of the Tuolumne River channel, at river mile 25.9 (Pool 9) where past instream gravel mining created a large deep lake area in the main channel. The channel was changed from a warmwater predator species habitat to a 400 to 500 foot wide riparian flood plain-recreating a riffle and run pattern that followed the restored meander channel of the river along with native vegetation planted on fill terraces in a mix similar to that found on undisturbed segments of the river. The project budget was $2.7 million.

The relatively low cost of these actions, and the fact that they could be funded incrementally, even though they are not likely reversible gives this bundle a moderately high funding feasibility.

3.4.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Actions undertaken to isolate captured gravel pits would be unlikely to be affected by climate change or seismic events. This bundle does not restore ecosystem processes that support species, but rather removes sources of direct mortality. This bundle is not easily adaptable or reversible, but the need to modify or reverse these actions would be unlikely.

3.4.4 Other Resource Impacts Criteria (#15-#17)

Isolating gravel pits would have minor effects on other native Delta species by avoiding becoming trapped and subject to predation. It would not affect other species outside the planning area.

The activities involved in Bundle #12 would involve a moderate amount of construction and associated human environment impacts, and would likely be less than #9 and 10, but more than #11 and 13. Socio-economic effects would only occur if the construction activities involved the removal of some land from agricultural or other income-producing uses to habitat purposes.

3.5 BUNDLE #13: INSTALLATION OF SCREENS ON RIVER DIVERSIONS UPSTREAM OF DELTA

Bundle 13 involves the installation of screens on river diversions upstream of Delta to reduce mortality of fish.

3.5.1 Biological Criteria (#1-#7)

3.5.1.1 Smelt (Delta and longfin)

Screening of diversions upstream of the delta is expected to have negligible to no effects on smelt.

3.5.1.2 Sturgeon (green and white)

Installation of fish screens on river diversions up stream of the Delta could slightly reduce non-natural mortality (SLC 1) of juvenile sturgeon. Reduction of mortality by screening would be highly variable and would depend on location and design of the unscreened diversions. Most of these diversions have their intakes off the bottom while juvenile sturgeon, passing down-stream to the Delta nursery areas, are known to hug the substrate. The highest chance of entrainment is to the down migrant juveniles during the summer.

Although screening will reduce entrainment, the effects on the population would be very low. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

3.5.1.3 Salmonids

The installation of screens on river diversions upstream of Delta will likely reduce entrainment mortality of salmonids (SLC 1). These screens may also reduce the number of non-native predators that are entrained, negatively impacting salmonids (LSC 5). The effect of this action on overall salmonid populations will depend on the number of upstream diversions. The majority of the larger water diversions have been retrofitted with positive barrier fish screens. As noted above, juvenile salmonids have a reduced vulnerability to entrainment at the smaller diversions, which reduces the potential benefits of this action.

The length of time required to improve habitat conditions will depend on the number of upstream diversions. As a result, it is difficult to determine the ability of this bundle to be implemented within a timeframe that meets the near term needs of salmonids (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.5.1.4 Splittail

The installation of screens on river diversions upstream of Delta could reduce entrainment mortality of splittail (SLC 1). These screens may also reduce the number of non-native predators that are entrained, negatively impacting splittail (LSC 5). Because these diversions are upstream of the Delta, the screens will likely have small positive effects on the splittail population and may be cancelled out by the potential increased mortality from non-entrained non-natives. Therefore, this bundle will have lower impacts on splittail compared to Bundles #9 and 10, and, depending on a variety of factors, will likely be in the range of Bundles #11 and 12.

The length of time required to improve habitat conditions will depend on the number of upstream diversions. As a result, it is difficult to determine the ability of this bundle to be implemented within a timeframe that meets the near term needs of splittail (SLC 7).

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

3.5.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. Fish screening technology, particularly on smaller diversions is a well established technology and is very feasible. Successful implementation of this bundle will require the voluntary participation of non-BDCP entities that operate the diversions. The willingness of Delta landowners and water districts to participate is unknown, and therefore the extent to which these diversions could be screened is unknown.

Costs to install and operate positive-barrier fish screens on un-screened upstream of Delta diversions will vary by number of un-screened diversion points, size of diversion, and geographic location. Costs can be highly specific to individual projects. CALFED analyzed costs to implement 42 fish screen projects funded through the ERP grant program. Construction costs totaled approximately $42 million. Costs for individual screening projects ranged between $15,000 and $6.0 million. Many of the screening projects were located upstream of the Delta.

The CALFED Draft Finance Options Report (Finance Options Report) utilized an average cost of $1 million per fish screen project to estimate the cost of screening un-screened diversions located within the Delta and along its tributaries. Using data on Central Valley diversions from the CVPIA EIS/EIR, the Finance Options Report estimated there were between 89 and 133 unscreened diversions. The report did not provide information on the geographic location of these diversions and therefore it is not know how many are upstream of the Delta. Assuming 1/2 to 3/4 of estimated un-screened diversions are upstream of the Delta, screening costs for bundle #13 may be in the range of $45 to $100 million. Because the assumed number of un-screened river diversions is highly speculative, a low degree of confidence should be given to this cost estimate.

The relatively low cost of these actions, the fact that they could be funded incrementally, and the fact that they are relatively easily reversible, gives this bundle a relatively high funding feasibility.

3.5.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Actions undertaken to screen diversions would be unlikely to be affected by climate change or seismic events. This bundle does not restore ecosystem processes that support species, but rather removes sources of direct mortality. This bundle is adaptable and easily reversible, but the need to modify or reverse these actions would be unlikely.

3.5.4 Other Resource Impacts Criteria (#15-#17)

Installing screens upstream diversion screens is not likely to affect other native species within the Delta. It could benefit, to a minor extent, native fishes that are currently entrained in upstream reservoirs.

Bundle #13 would have relatively little impact on the human environment. The construction activities and associated impacts to the human environment would be relatively small and short-term. Socio-economic effects would also be relatively small.

4.0 FLOW-RELATED HABITAT IMPROVEMENT BUNDLES

4.1 BUNDLE #14: OPERATE THE DELTA CROSS CHANNEL (DCC) TO IMPROVE PASSAGE

Bundle 14 involves operation of the Delta Cross Channel (DCC) to improve passage for salmonids:

- 14a. Operate the DCC to improve passage of Sacramento River steelhead and salmon and minimize adverse effects on Sacramento River fish associated with moving into the Central Delta

4.1.1 Biological Criteria (#1-#7)

4.1.1.1 Smelt (Delta and longfin)

Operation of the DCC to benefit salmonids is expected to have negligible to no effects on smelt.

4.1.1.2 Sturgeon (green and white)

Under the current method of operation the DCC will have very little effect on sturgeon. The DCC gates are left open from June to December. Juvenile sturgeon out-migrate and disperse to their nursery grounds, the Delta, during the summer to early fall. The benefits to sturgeon of this bundle are minimal.

Sturgeon spend one to four years in the fresh waters of the Delta nursery areas before leaving for salt water environments. This indicates that resident time in the Delta is not a problem for these species. It is beneficial for sturgeon to reach the Delta unhindered. Therefore, the effect of this action on the population is expected to be very low. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

4.1.1.3 Salmonids

The DCC is currently closed from February through late May to provide protection for migrating juvenile salmonids. This action would extend the duration of gate closures. Operating the DCC to improve passage would likely reduce mortality of juvenile salmonids from the Sacramento River and tributaries outmigrating. These individuals would not move into the inner Delta via the DCC, which is thought to decrease survival of juvenile salmonids (SLC 1). The effect of this action is likely to be moderately low since the gates are currently closed during a majority of the migration period. This action would benefit even more by controlling fish passage into the interior Delta via Georgiana Slough (see #15).

Operating the DCC to improve passage could increase water quality and flow conditions (SLC 2) for salmonids downstream because the water that would flow into the DCC would instead flow directly down the Sacramento River. This effect on overall salmonid abundance is likely low, however, because the DCC is currently closed during a majority of the migration period.

Implementation of this bundle will likely go quickly (SLC 7), with the major impediment being agreement by all interested parties in the timing of gate operation. Therefore, there is high certainty that this bundle will likely be within a timeframe to meet salmonid needs.

Based on the available information, the certainty of the assessment of this bundle is considered high.

4.1.1.4 Splittail

Closing the DCC would likely increase water quality and flow conditions (SLC 2) for adult splittail downstream because the water that would flow into the DCC would instead flow directly down the Sacramento River. This effect on overall splittail abundance is likely low, however, because splittail can tolerate a wide range of water quality conditions.

Implementation of this flow improvement bundle will likely go quickly (SLC 7), with the major impediment being agreement by all interested parties in the timing of gate operation. Regardless, timing of the implementation will likely not have major impacts on the splittail population.

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

4.1.2 Planning Criteria (#8-#10)

The DCC is opened to allow fresh water from the Sacramento River to enter the Central Delta and be transported to the export facilities in the south Delta. If the new operations of the DCC involved having the DCC closed more than under current conditions, it would likely result in a degradation of water quality at the export pumps. This could lead to reduced exports, if salinity at the pumps exceeds allowable levels more frequently as a result of this change.

Many studies have been conducted over the past few years that have led to a much better understanding of fish behavior at or near the DCC. There are no engineering feasibility implementation issues associated with this bundle. Implementation of this bundle can be accomplished with existing facilities and therefore do not entail any significant additional capital costs. As this bundle would not entail any new capital costs, the funding feasibility for this bundle is very high.

4.1.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Operation of the DCC gates for the benefit of covered fish species would not be affected by climate change, seismic events, or levee failures to the extent that the DCC gates are not rendered inoperable by seismic or other catastrophic event. These factors, however, may change how the DCC may operated in the future to achieve benefits (e.g., if future levee failures change how water is routed through the Delta, the periods that the DCC operates may change).

This bundle does not restore ecosystem processes that support species, but rather removes/reduces the likelihood for false passage into the central Delta from the Sacramento River. This bundle is highly adaptable and reversible because operations can easily be adjusted if needed.

4.1.4 Other Resource Impacts Criteria (#15-#17)

Operation of the DCC gates to provide benefits for migration and transport of Sacramento River salmonids is not expected to measurably affect other native aquatic species inside or outside the BDCP planning area..

If reoperation of the DCC leads to higher salinities in water exports, it could lead to reductions in agricultural productivity in export areas, and perhaps in the southern Delta due to return flows to the San Joaquin River. It could also lead to increases in cost for the treatment of water in urban export areas or increased health risks resulting from higher salinity and other constituents.

4.2 BUNDLE #15: OPEN THE DCC AND INSTALL SCREENS AT THE DCC AND GEORGIANA SLOUGH

Bundle 15 involves changes in the DCC, including opening of the DCC and installation of screens at the DCC and Georgiana Slough for the benefit of salmonids.

4.2.1 Biological Criteria (#1-#7)

4.2.1.1 Smelt (Delta and longfin)

This bundle is expected to have negligible to effects on smelt.

4.2.1.2 Sturgeon (green and white)

Opening the DCC and installing screens at the DCC and Georgiana Slough could have a negative impact on sturgeon by limiting juvenile sturgeon access (SLC 3) to central and central-east delta rearing habitats. Sturgeon spend one to four years in the fresh waters of the Delta nursery areas before leaving for salt water environments. This indicates that resident time in the Delta is not a problem but an essential for these species. It is beneficial for sturgeon to reach the Delta unhindered. Therefore, the effect of this action is expected to be negative. Population impacts are probably medium to low.

Screens will also delay juvenile sturgeon from accessing these delta rearing areas food supplies (SLC 4) and could increase the concentration of juvenile sturgeon in other Delta areas. Population impacts are probably medium to low.

Implementation of this action would be a medium time frame (SLC 7) relative to other bundles and would not meet the needs of these species because effects would likely be negative.

Implementation of this bundle would have a low negative impact on the sturgeon population. Based on the available information, the certainty of the assessment of this bundle is considered moderate.

4.2.1.3 Salmonids

Installing screens at the DCC and Georgiana Slough would likely reduce mortality of outmigrating juvenile salmonids from the Sacramento River and tributaries. Individuals that are screened out would not move into the interior Delta, which is thought to decrease survival of juvenile salmonids (SLC 1). The effect of this action is likely moderately high. The effectiveness of this action would likely be greater than simply closing the DCC since positive barrier fish screens have been shown to be effective for salmonids and this action would also eliminate salmonid passage into the interior Delta through Georgiana Slough. The effect of this action on the salmonid population could be relatively high.

This bundle will likely decrease water quality and flow conditions (SLC 2) for salmonids downstream because the water that would flow directly down the Sacramento River would flow into the interior Delta instead. There is a high degree of uncertainty regarding the net benefits that would be experienced by salmonids from reduced passage into the interior Delta versus the reduction in flows within the lower Sacramento River. In general it is thought that the benefits of screening would substantially outweigh the uncertainty of incrementally reduced river flows This effect on overall salmonid abundance is likely low

Implementation of this bundle will likely go quickly (SLC 7), will take an intermediate amount of time because the screen will need to be designed and constructed. Therefore, it will be implemented moderately quickly to meet the needs of salmonids.

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

4.2.1.4 Splittail

This bundle will likely decrease water quality and flow conditions (SLC 2) for adult splittail downstream because the water that would flow directly down the Sacramento River would flow into the central Delta instead, where it is likely that temperature will increase, DO will be reduced, salinity will increase, and toxics will increase (from farming). This effect on overall splittail abundance is likely low, however, because splittail can tolerate a wide range of water quality conditions. Splittail may be restricted from food resources in the interior Delta as a result of the closure of the DCC (SLC 4). The effect of this restriction to the overall population, however, is expected to be minimal because the interior Delta is not a preferred habitat.

Implementation of this bundle will likely go quickly (SLC 7), but will take an intermediate amount of time because screen will need to be designed and constructed. Regardless, timing of the implementation will not have major impacts on the splittail population.

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLC 7.

4.2.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The two fish screens that are part of Bundle #15 would be very large, but large fish screens (GCID) have been successfully built on the Sacramento River. The DCC and Georgiana Slough fish screens would present engineering challenges but are considered feasible. One potential impediment to the construction of the DCC fish screen is the possibility that constructing the screen would impinge on the historic town of Locke which is on the National Register of Historical Places.

Two 2,000-feet long fish screens to separate Sacramento fish from the DCC and Georgiana Slough flows to the Mokelumne and San Joaquin River channels would be required. The fish screens would be similar to the Glenn-Colusa Irrigation District (GCID) screen, but would include a 5-feet high concrete panel at the bottom and a 10-feet high concrete panel at the top. The GCID fish screen project had a $76 million capital cost.[17] The project constructed a 620-feet

[17] http://www.gcid.net/documents/gcid%20brochure%20pdfs/Fish_protection.pdf

extension to the existing interim GCID fish screen, with an average cost of about $12.3 million per 100-feet of screen. Applying this average unit cost to the two proposed fish screens suggests that screening costs for Bundle #15 may be on the order of $500 million.

The capital costs of the two fish screens would be moderately high, the projects could not be implemented incrementally, and would be relatively irreversible. It is not known how controversial this project would be. Thus, this bundle would have only a moderate funding feasibility.

4.2.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Operation of the DCC gates for the benefit of covered fish species would not be affected by climate change, seismic events, or levee failures to the extent that the DCC gates are not rendered inoperable by seismic or other catastrophic event; however, the screens could be subject to seismic events if not designed to withstand an event. These factors, however, may change how the DCC may operate in the future to achieve benefits (e.g., if future levee failures change how water is routed through the Delta, the periods that the DCC operates may change).

This bundle does not restore ecosystem processes that support species, but rather removes/reduces the likelihood for false passage into the central Delta from the Sacramento River. This bundle is highly adaptable and reversible because operations can easily be adjusted if needed. The two screens that are part of Bundle #15 would be very large and expensive to build. They would be reversible, in that they could be removed if necessary, but it would be expensive to do so.

4.2.4 Other Resource Impacts Criteria (#15-#17)

Opening the DCC gates to provide benefits for salmonids is not expected to measurably affect other native aquatic species inside or outside the BDCP planning area.

The two fish screens included in Bundle #15 would involve a high amount of construction and associated human impacts to the environment compared with other Flow-Related Habitat Improvement bundles. Socio-economic effects would only occur if the construction activities involved the removal of some land from agricultural or other income-producing uses.

4.3 BUNDLE #16: RE-OPERATION OF UPSTREAM STORAGE FACILITIES TO IMPROVE RIVERINE AND DELTA HABITATS

Bundle 16 includes elements that involve the reoperation of upstream storage facilities for the purpose of improving riverine and Delta habitats:

- 16a. Re-operation of upstream storage facilities for cold water pool management for benefit of riverine fish
- 16b. Re-operation of upstream storage facilities to improve Delta in-flow for benefit of estuarine fish
- 16c. Re-operation of upstream storage facilities to improve in-stream flows for benefit of riverine fish

4.3.1 Biological Criteria (#1-#7)

4.3.1.1 Smelt (Delta and longfin)

This bundle is expected to have negligible to effects on smelt.

4.3.1.2 Sturgeon (green and white)

Re-operations of upstream storage facilities to improve riverine and Delta habitats with additional releases to improve flows and manage temperatures of cold water pools would moderately improve the condition and survival of all life stages of sturgeon upstream of the Delta by maintaining desirable water temperatures (SLC 2). Adult green sturgeon require pools to seek refuge and cool waters in summer. During droughts and summer heat waves, cold water releases are more essential. Population level effects are expected to be medium.

The effects of increased or pulse release flows would be moderately beneficial to sturgeon habitat (SLC 3) by the creation of attractant flows, barrier passage flows, and improve the quality and quantity of over summer habitat. The degree of benefit will be site specific (river or reach). Adult sturgeon up-migrate for spawning starting with white sturgeon in February to June with green sturgeon. Monitoring sturgeon activity on the Feather River has shown that flow timing and quantity is important for attraction to the river, passage beyond barriers, and access to some spawning areas. The expansion of range or improvement of numbers of sturgeon in separate drainages is essential to population resiliency. Population level effects should be medium to high.

Implementation of this action could be fast relative to other bundles (SLC 7) and could meet the short-term needs of these species.

Beneficial effects of this bundle on the sturgeon population would likely be medium to high. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

4.3.1.3 Salmonids

Re-operation of upstream storage facilities will likely increase water quality and especially flow conditions needed by salmonids for passage, spawning, and rearing(SLC 2). Therefore, this action will likely have moderately high beneficial impacts on overall salmonid populations.

Re-operation of upstream storage facilities may provide upstream spawning habitat below the reservoirs for salmonids by increasing flows out of the reservoir (SLC 3).

If lower quality, non-native prey species of salmonids have out competed higher quality, native prey species (as has been discussed among experts), the return of more natural flows could improve conditions for natives, leading to an increase in their abundance that would benefit salmonids (SLC 4). This mechanism is moderately speculative and is based on multiple assumptions. Thus, re-operation of upstream storage would likely have a small to moderate effect on overall salmonid populations.

Re-operation of upstream storage facilities could have moderate impacts on reducing abundances of non-native competitors and predators of salmonids (SLC 5) for reasons discussed in the previous paragraph.

Re-operation of upstream storage facilities should improve ecosystem processes related to salmonids (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which Central Valley salmonids evolved. Salmonids could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

This bundle would likely be the quickest of the flow-related improvement bundles to be implemented (SLC 7). There is no physical structure to be built, as reservoir release tools are already in place. The only roadblock would be an agreement among users.

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLCs 3 and 7.

4.3.1.4 Splittail

Re-operation of upstream storage facilities should increase water quality and flow conditions for splittail (SLC 2). However, due to the tolerance of splittail to a wide variety of environmental conditions, this effect will be only moderate to the overall splittail population.

Re-operation of upstream storage facilities could increase accessibility of floodplain habitat to splittail for spawning (SLC 3) if releases are of sufficient volume to provide for overbank flows. It was generally agreed upon in BDCP Technical Meetings that the reduction in quantity of and accessibility to suitable spawning habitat is one of the top stressors of splittail populations, particularly the duration of flooding needed for successful spawning and rearing (estimated at 6-8 weeks). This bundle, along with #17, will have the greatest positive effect on the overall splittail population.

If lower quality, non-native prey species of splittail have outcompeted higher quality, native prey species (as has been discussed among experts), the return of more natural flows could improve conditions for natives, leading to an increase in their abundance that would benefit splittail (SLC 4). This mechanism is moderately speculative and is based on multiple assumptions. Therefore, this action would likely allow for possible small positive impacts on the splittail population.

Re-operation of upstream storage facilities could have moderate impacts on reducing abundances of non-native competitors and predators of splittail (SLC 5) because it may provide conditions not be amenable to non-native species. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives.

Re-operation of upstream storage facilities should greatly improve ecosystem processes related to splittail (SLC 6). A return to more natural hydrologic conditions would allow the ecosystem to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

This bundle would likely be the quickest of the flow-related improvement bundles to be implemented (SLC 7). There is no physical structure to be built, as reservoir release tools are already in place. The only holdup would be an agreement of the release logistics among users, which could take a long time.

Based on the available information, the certainty of the assessment of this bundle is considered high, except for SLCs 4 and 7.

4.3.2 Planning Criteria (#8-#10)

The actions contained in Bundle #16 would likely reduce the amount of water available for export and therefore would not achieve the water supply goals of the SWP and CVP PREs. This water would be released when it would improve downstream aquatic habitat conditions but it is likely that much of this water could not be exported (due to regulatory restrictions in pumping, lack of pumping capacity, lack of south-of-Delta conveyance capacity, or lack of south-of-Delta storage capacity).

Bundle #16 is generally feasible, since it only involves reoperation of storage facilities. However, meeting specific downstream habitat needs may be constrained by the needs of senior water rights holders on the river, limitations on flows due to flood control requirements, and other physical and legal factors specific to each situation. Actions within bundle #16 can be accomplished with existing facilities and therefore do not entail any significant additional capital costs. As this bundle would not entail any new capital costs, the funding feasibility for this bundle is very high.

4.3.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Future changes in hydrology associated with climate change may limit flexibility of upstream reservoir releases in future years. Operation of reservoirs to provide beneficial flows (e.g., support transport and upstream migration, water temperatures for spawning and rearing, overbank flooding to support spawning and rearing) would restore flow-related ecological processes that historically supported covered fish and their habitats. This bundle, however, would require ongoing operation of storage facilities to provide for winter/spring overbank flows and maintenance of floodway weirs and any other structures required to maintain fish access and drainage. This bundle is highly adaptable and easily reversible in that releases could be easily modified (within the constraints of other operational requirements) to be modified over time if needed.

4.3.4 Other Resource Impacts Criteria (#15-#17)

Reoperation of upstream storage facilities to improve Delta inflow conditions for covered fish species would be expected to benefit upstream and in-Delta conditions for other native species that have evolved under similar hydrologic conditions as the covered fish species. Hydrologic and salinity changes could have minor effects on the seasonal distribution of some aquatic species. It would have no substantial impacts to the human environment, and would only have socioeconomic impacts if reoperations led to reduced exports.

4.4 BUNDLE #17: IMPROVEMENT AND CREATION OF BYPASS AND FLOODWAY HABITAT (E.G. YOLO BYPASS, COSUMNES FLOODWAY)

Bundle 17 involves the improvement and creation of habitat in bypasses and floodways:

- 17a. Manage bypasses and restore floodways within and upstream of the Delta to improve habitat

4.4.1 Biological Criteria (#1-#7)

4.4.1.1 Smelt (Delta and longfin)

This bundle is expected to have negligible to effects on smelt.

4.4.1.2 Sturgeon (green and white)

Improving and creating bypass and floodway habitats could moderately reduce direct non-natural mortality of sturgeon (SLC 1). However, improvements to the limited connectivity in the Yolo Bypass, the reduction of indirect losses (loss of eggs) may be more significant. Sturgeon in large numbers can enter the Yolo Bypass and experience stranding or significant migration delays that lead to the termination of spawning behavior. The impact of sturgeon stranding and migration delays is highly variable and dependent on hydrologic conditions. Even though in some years there are large numbers of sturgeon that are delayed or stranded, the likely effect on population abundance in most years will be moderate to low.

Improvements to riparian cover, channel conditions, and channel connectivity in the bypasses and floodways would significantly improve water quality and flow conditions (SLC 2) at those sites. A restored more natural habitat in the bypasses and floodways would improve the natural flushing in those areas by buffering temperature spikes and DO sags. Cooler waters with higher oxygen level would lower the stress in sturgeon and help maintain their health as they wait for the next pulse of water. The effects of this bundle on improving water quality will be variable and site specific. Therefore, the water quality effect of this bundle is expected to be moderate to low.

Habitat improvements (SLC 3) of bypasses and floodways with channel (drainage) reconstruction and improved access would slightly improve the overall availability of desirable habitat for sturgeon. Floodplains are rich food producers and flooded land generally has good protective cover. Studies in the Yolo Bypass have shown that juvenile fish passing through the bypass are larger and have a higher condition factor than fish passing down the river corridor. This should result in a higher survival ratio and would only occur during years with major flood events. Since sturgeon only use floodplains during migration and these advantages are only available during flood events, the benefits of this bundle on sturgeon habitat are short lived in the life cycle of sturgeon. Therefore, the habitat improvements on the floodplains would have a low beneficial effect on the population.

Habitat improvements of bypasses and floodways with channel (drainage) reconstruction and improved access would moderately improve overall food supply (SLC 4) on the floodplains and downstream in the Delta. Floodplains are rich food producers. Studies in the Yolo Bypass have shown that juvenile fish passing through the bypass are larger and have a higher condition factor than fish passing down the river corridor. This should result in a higher survival ratio of out migrants and would also, to a lesser degree, benefit sturgeon in their Delta nursery grounds. Increased carbon input via floodplains would increase Delta food availability (SLC 6). The benefits of this bundle on sturgeon food quantity and quality will fluctuate and are dependent on hydrologic conditions. Even though in some years the floodplain food supply contributions are large, the likely effect on population abundance in most years will be moderate to low.

Habitat improvements on existing floodplains with the removal of passage impediments could increase species abundance and meet short-term needs of sturgeon (SLC 7). Creation of new floodplains would create similar benefits on a longer period.

Beneficial effects of this bundle on sturgeon populations would likely be medium if large areas are improved. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

4.4.1.3 Salmonids

Improvement and creation of floodplains will likely have moderately large benefits to the overall salmonid population. Mortality (SLC 1) by non-natives may be lower on floodplains because the habitat may be too shallow for predators like striped bass (SLC 5). Salmon that use floodplain habitat in their outmigration tend to be much larger (presumably by a higher quantity or quality of food; SLC 3). Improvement and creation of floodplains should greatly improve ecosystem processes related to salmonids (SLC 6). An increase in floodplain habitat would allow the ecosystem to function more similarly to the system in which it evolved to function. Salmonids could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

This bundle would likely take the longest of the flow-related improvement bundles to be implemented (SLC 7) depending on the amount of floodplain habitat to be improved or created (e.g., levee setbacks, regarding channels, etc.). In contrast, increasing the frequency and duration that currently existing bypass areas of seasonally flooded could be implemented quickly.

Based on the available information, the certainty of the assessment of this bundle is considered high.

4.4.1.4 Splittail

Improvement and creation of floodplains will likely have major benefits to the overall splittail population (SLC 3). It was generally agreed upon in BDCP Technical Meetings that the reduction in quantity of and accessibility to suitable spawning habitat is one of the top stressors of splittail populations, particularly the duration of flooding needed for successful spawning and rearing (estimated at 6-8 weeks). This bundle, along with #16, will have the greatest positive effect on the overall splittail population.

This bundle would likely greatly increase food quality, quantity, and accessibility by splittail (SLC 4). Splittail could potentially benefit from an increase in access to prey on floodplains (reproductive splittail often consume earthworms and other terrestrial organisms in floodplains). In addition, floodplains are highly productive and, if flooded, they could provide high levels of productivity into the Delta system. It is thought that growth of juveniles is fastest on floodplains because of improved food resources. Therefore, this effect of this bundle on food abundance, quality, and accessibility will likely have a high effect on the overall splittail population.

Improvement and creation of floodplains should greatly improve ecosystem processes related to splittail (SLC 6). Before humans began manipulating the configuration of the Delta, much of the area was a floodplain. Therefore, an increase in floodplain habitat would allow the ecosystem to function more similarly to the system in which it evolved to function. Splittail could potentially benefit by increased native prey of higher quality and increased productivity from natural floodplain inundation.

This bundle would likely take the longest of the flow improvement bundles to be implemented (SLC 7) depending on the amount of floodplain habitat to be improved or created.

Based on the available information, the certainty of the assessment of this bundle is considered high.

4.4.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. Creation and management of floodways is a proven technology, therefore, the actions that would be undertaken to implement this bundle are expected to be technically feasible. The ability to obtain lands for creating new floodways from willing participants, however, may constrain the ability for their creation. The rapid urbanization of the Central Valley and the Delta restricts the land available for the expansion or creation of floodways. The cooperation of local landowners and regulatory agencies would also be needed to make improvements to existing floodways to improve habitat values. Physical and hydraulic constraints associated with individual projects could put restraints on habitat improvements. Finally, the creation of a new floodway could involve the conversion of an existing land use that supports listed terrestrial species.

Costs for bundle #17 will vary by type, extent, and location of physical habitat restoration projects. The CALFED ERP program funded nine floodway habitat acquisition and restoration projects between 1997 and 2001. These projects targeted approximately 7,500 acres for restoration at a total cost of about $43 million. Costs ranged between $2,500 and $9,400 per acre. The average cost per acre to acquire and restore floodway habitat for these projects was approximately $5,800. These unit costs could be coupled with habitat acquisition and restoration levels as they become available to generate preliminary cost ranges for alternative levels of floodway acquisition and restoration.

The capital costs associated with this bundle are not known, but are likely to be moderate (tens to hundreds of millions of dollars). The actions are relatively irreversible, and large-scale commitment of private lands for this purpose is likely to be controversial. On the other hand, the actions could be funded incrementally. Therefore, the funding feasibility of this bundle is moderate.

4.4.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Sea level rise could adversely affect restored intertidal and ripiarian habitats within the Delta. Selecting sites that have available adjacent upland will allow intertidal and riparian habitat to be maintained as sea level rises. Without adjacent upland areas, intertidal habitat may become subtidal habitat.

Actions that restore accessibility of covered fish species to floodways and that provide for annual flooding of floodways would restore ecosystem processes that historically supported fish spawning and rearing along the Sacramento River and SJR. This bundle, however, would require ongoing operation of storage facilities to provide for winter/spring flows to inundate floodways and maintenance of floodway weirs and any other structures required to maintain fish access and drainage. This bundle is moderately adaptable in that floodplain habitat conditions can be readily modified through changes in operations or modification of weirs or other structures that regulated passage into floodways. Improvements to floodways could be reversed, though they would likely be very expensive. Creation of new floodways could also be reversed, and the land sold to private parties. However, it would be very difficult from a economical and political standpoints.

4.4.4 Other Resource Impacts Criteria (#15-#17)

Improvements and management of floodways would benefit other native species inside and outside the Delta and planning area. Bundle #17 would provide high quality habitat for native fishes that forage, spawn, and rear in inundated floodplain habitats, as well as for waterfowl and other water birds, wading birds, and migrant shorebirds. This bundle is expected to provide the greatest benefits for other native species among bundles #14-#17.

The creation of new floodways would create large impacts on the human environment, mainly socio-economic impacts. In all likelihood, land acquired through fee title sale would take land out of agricultural production, and land on which flood easements were purchased would result in reduced economic potential for the land.

5.0 PHYSICAL RESTORATION BUNDLES

5.1 BUNDLE #18: RESTORE PHYSICAL HABITAT IN THE NORTH, EAST, AND WEST DELTA

Bundle 18 includes elements that involve the physical restoration of habitat in the north, east, and west Delta:

- 18a. Design in-Delta levee maintenance projects to incorporate features that improve in-channel habitat conditions (e.g., establishment of riparian vegetation on levee slopes to provide shaded riparian area (SRA) overhead cover, creation of levee benches to create shallow inter-tidal and subtidal habitat areas, incorporation of large wood debris into riprap within the intertidal and subtidal portions of the levee cross section). Actions of this measure are limited to opportunities presented by levee maintenance needs
- 18b. Extensive in-Delta Levee setbacks in important covered fish use areas to establish intertidal and subtidal aquatic and floodplain habitats.
- 18c. Extensive restoration of aquatic and floodplain habitats on existing farmed islands by breaching levees to reintroduce tidal flow and elevating island interiors to elevations that will support desired covered species habitats. Island habitats will be designed to provide a diversity of habitats to ensure that the range of habitats conditions required for covered fishes are established and to create conditions that will maximize food production. Location of restorations depend on operations.

5.1.1 Biological Criteria (#1-#7)

5.1.1.1 Smelt (Delta and longfin)

Restoring Delta habitat would be expected to have a small incremental effect on water quality and hydrologic conditions as a result of changes to channel cross-sectional profiles, and creation of additional shallow-water habitat (SLC 2). Modifications to habitat conditions within the Delta could have a substantial effect on habitat quality and availability for Delta smelt. Improvements to habitat conditions have the potential to increase the availability of suitable spawning habitat (recognizing that the specific locations where smelt spawning occurs are unknown). Improving habitat quality and availability would be expected to also increase production of zooplankton and thereby improve food availability for various life-history stages of smelt. Habitat improvements within the north Delta would have a high value for smelt (SLC 3).

Modifications to habitat within the Delta has the potential to result in substantial increases in primary and secondary production of both phytoplankton zooplankton through increased residence time, providing additional shallow water habitat for colonization by emergent aquatic vegetation, increased production of organic carbon, and improved availability of bio-available nutrients. The magnitude of these potential benefits is unknown, but would depend in part on the location, areal extent, and design of habitat enhancement features. Improvements to habitat quality and availability would potentially have a moderate benefit on food availability for smelt within the Delta (SCL 4).

The effects of habitat improvements on the relative abundance of non-native fish species are largely unknown. Two competing hypotheses exist which include: (1) increasing habitat diversity and complexity will benefit natives fish species through opportunities to colonize high-quality habitat to support various life-history stages and thereby provide a competitive advantage to native fish species; and (2) creation of additional high-quality aquatic habitat will provide opportunities for non-native fish species to expand their geographic distribution and abundance, create habitat conditions favorable to non-native fish species, and create opportunities for additional predation in competition between native and non-hyphenated species. The relative benefits of habitat enhancement for native species depend in large part, on the habitat characteristics and their suitability for native fish species (SLC 5).

Habitat enhancement, including the creation of additional shallow-water habitat, increases in hydraulic residence time, increases in habitat diversity and complexity, and other habitat attributes would all be expected to contribute substantially to improve ecosystem processes within the Delta when compared to existing baseline conditions (SLC 6).

The design, permitting, and construction of habitat improvements requires potentially land acquisition, levee setbacks, changes in land use, and other modifications that may require a substantial period of time to implement. Large-scale improvements to habitat quality and availability within the Delta are anticipated to take a decade or longer to implement (SLC 7).

5.1.1.2 Sturgeon (green and white)

Restoration of physical habitats in the north, east and west Delta with improved levee habitat conditions, levee setbacks and island breaching would provide more desirable habitat (SLC 3) to young sturgeon improving condition and survival. Juvenile sturgeon out-migrate and disperse to their nursery grounds, the Delta, during the summer to early fall. Sturgeon spend one to four years in the fresh waters of the Delta nursery areas before leaving for salt water environments. Therefore, habitat improvements throughout the Delta could have a moderate to high beneficial effect on the population.

Restoration of physical habitats in the Delta would increase abundance of vegetated shallow water habitat that should increase the abundance and diversity of food available to sturgeon (SLC 4). Access to the flooded island areas may improve overall survival and growth of sturgeon due to greater food quality and quantity, and possibly better cover. Population effect of this bundle on juvenile sturgeon food supply would be expected to be moderate to high.

Restoration in the Delta will increased carbon input via floodplains and vegetation of riparian zones, would increase Delta food availability (SLC 4). The effect of this action on this element could be moderate, but the degree is dependent on the area of restoration.

Delta levee breaches could increase species abundance and meet short-term needs of sturgeon. Creation of new or improved riparian zones as levee maintenance is preformed would create similar benefits but to a lesser degree on a longer period (SLC 7).

Beneficial effects of this bundle on sturgeon populations would likely be medium to high if large areas were improved. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

5.1.1.3 Salmonids

Restoration of physical aquatic habitats in the north, east, and west Delta would likely have low benefits to the salmonids at the population level under existing habitat conditions upstream of the Delta. The benefits of restoring Delta habitat for salmonids, however, would likely increase if upstream spawning and rearing habitats were restored and the number of smolts entering the Delta were increased. Mortality from non-native predators could be reduced as a result of creating habitat conditions that disfavor predators and provide cover for smolts (SLC 1 and SLC 5). Restoration of extensive habitat areas would be expected to increase food production by increasing residence time of water. Increased food production could increase the period that smolts reside in the Delta before migrating downstream, thus improving the condition of fish reaching the Bay and possibly increasing survival (SLC 3 and SLC 4). With the exception of control of invasive non-native plants and levee maintenance, restored habitats would be expected to be supported by ecological processes, assuming that habitats are restored to elevations that provide the surface and subsurface hydrologic conditions necessary to support desired vegetation and other habitat elements (e.g., water depth, water velocity) (SLC 6).

This bundle would likely take longer than Bundles #21 and 22 to implement because of the time likely required to secure the extent of lands necessary for full implementation and to resolve uncertainties associated with designing functioning habitat in an estuarine environment (SLC 7).

5.1.1.4 Splittail

This habitat restoration bundle (HRB) would likely have a moderate impacts on water quality (SLC 2) for splittail because the restoration would allow water conditions that mimic historical conditions (residence time of water in the Delta system influences temperature, DO, and load of nutrients and particulate matter). However, because splittail tolerate a wide variety of environmental conditions, the influence on water quality will have a minimal effect on the overall population.

By providing extensive habitat (spawning and juvenile rearing) for splittail (SLC 3), this HRB (as with 19 and 20) would likely have the greatest impact on the overall population of any conservation strategy bundle. This is particularly true of the east Delta, where there is little suitable juvenile rearing habitat. It was generally agreed upon in BDCP Technical Meetings that the reduction in quantity of and accessibility to suitable spawning habitat is one of the top stressors of splittail populations. This HRB would benefit even more if the salinity in the Delta were allowed to fluctuate naturally because it would restore large areas of shallow brackish water habitat (adult habitat) in the Delta that are currently strictly freshwater.

This HRB would likely greatly increase food quality, quantity, and accessibility by splittail (SLC 4) in the same way as Bundle #17. However, it should have a greater impact on the overall splittail population than Bundle #17 because a wider range of habitat (spawning, juvenile rearing, and some adult) would be restored.

This HRB could possibly reduce the number of non-native predators and competitors by creating habitat in which natives evolved (SLC 5). By doing so, natives may have a competitive edge over non-natives. There is relatively high uncertainty that the change in hydrological conditions would eradicate all non-natives. Non-native species that have established in the

Delta planning area are generally resilient to wide variety of environmental conditions. Although they may prefer a certain set of conditions, they may be able to adapt to other sets of conditions. This is the nature of invasive species.

This HRB would likely greatly improve ecosystem processes related to splittail (SLC 6) in a similar way as Bundle #17. However, it should have a greater impact, albeit still limited, on the overall splittail population than Bundle #17 because a wider range of habitat (spawning, juvenile rearing, and some adult) would be restored.

This bundle could potentially take a long time to be implemented (SLC 7) depending on the amount of habitat to be restored.

Based on the available information, the certainty of the assessment of this bundle is considered high.

5.1.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The restoration of physical habitat in the Delta faces many practical hurdles. First, most of the land is in private ownership, so any changes to levee maintenance practices, the creation of setback levees, or the flooding of islands would require the willing participation of these landowners. Second, many islands in the Delta have subsided and are currently up to 20 feet below sea level. Although some success in halting or reversing subsidence by growing tules has been achieved, it is a very slow process. On the other hand, raising elevations by importing soil would require vast amounts of material and would be extremely expensive. Third, the U.S. Army Corps of Engineers is considering decertifying levees that support vegetation, so improving habitat on levees that protect islands may not be feasible. Fourth, recent attempts to restore shallow water habitats in the Delta have had mixed results, with the habitats being colonized by invasive and non-native species to a larger extent than by native species. This problem will likely need to be resolved before large-scale restoration efforts are undertaken.

Costs for bundle #18 will vary by type, extent, and location of physical habitat restoration projects. The CALFED Draft Finance Options Report evaluated costs for ERP projects funded by grants between 1997 and 2001. This analysis estimated cost ranges for Delta habitat acquisition, terrestrial/marsh habitat restoration, and instream habitat restoration, as shown in the following table.

Cost Range	Land Acquisition ($/Ac)	Terrestrial Restoration ($/Ac)	Instream Restoration ($/Mi)
Low	$3,100	$500	$70,000
High	$3,700	$2,000	$280,000

These unit costs could be coupled with habitat acquisition and restoration levels as they become available to generate preliminary cost ranges for alternative levels of restoration.

The "eco-Delta" alternative described by PPIC in its 2007 report *Envisioning Futures for the Sacramento-San Joaquin Delta* provides an upper-bound of possible costs associated with the elements in bundle #18. Components of "eco-Delta" included (1) flooded islands providing habitat for pelagic species and discouraging undesirable invasive species, (2) inland islands managed as freshwater wetlands for duck hunting and other purposes, (3) islands managed for upland foraging habitat for sandhill cranes and other wintering waterfowl (presumably by wildlife-friendly farming), and (4) large expanses of peripheral areas restored to some resemblance of the historical Delta (e.g., Suisun Marsh, Cache Slough region, Cosumnes River floodplain). PPIC estimated capital costs to undertake the full range of restoration actions described by the "eco-Delta" alternative would be on the order of several billion dollars.

The capital costs associated with this bundle would be high. Although the actions are not easily reversible and large-scale acquisition of private lands is likely to be controversial, the funding feasibility of this bundle is considered high because:

- restoration of Delta habitats can be implemented incrementally;
- the need for restoration has been identified (e.g., CALFED ERP) and is generally recognized by a large segment of the public as an important component of actions that need to be undertaken to address the health of the Delta
- the history of prior large-scale commitment of state and federal funding for Delta restoration projects, and
- current legislative proposals for additional Delta restoration funding.

5.1.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Setback levees that breach as a result of a seismic event or other factor could result in scour and loss of restored habitats at and near the breach site. If island levees breach and flood through an unplanned event, the resultant deep water habitat may be of lesser value to some covered fish species than if the island were restored as intertidal or shallow subtidal habitat. Sea level rise in future years may shift restored intertidal habitats to subtidal habitats. Restoring islands in the western Delta that would significantly increase the active tidal prism may increase local tidal dispersion and cause an overall increase in Delta salinity. Improving levees and/or restoring selected islands to intertidal or shallow subtidal water habitat may decrease overall risk to the system by removing potential failure points.

Restoration of aquatic, marsh, and floodplain habitats by setting back levees and breaching island levees are expected provide the physical habitat conditions required by covered species. With the exception of control of invasive non-native plants and levee maintenance, the need for ongoing human interventions to maintain habitats is expected to be minimal, assuming that habitats are restored to elevations that provide the surface and subsurface hydrologic conditions necessary to support desired vegetation and other habitat elements (e.g., water depth, water velocity). The degree and frequency of interventions required to control some of the invasive non-native plant species that currently hinder restoration of Delta habitats will depend the selected water operations and conveyance bundle. It is currently hypothesized that restoring variable hydrology and salinities to the Delta will disfavor some invasive species and thus reduce the need for periodic control of these species. Setback levees will need to be periodically maintained to prevent levee failures or repaired in the event of levee failures to prevent the future loss of channel side habitats from scour along segments of breached levee.

Habitat restoration measures are adaptable to the extent that future restoration projects can be modified based on performance monitoring of previous projects to improve species benefits. Modifying the conditions of existing restored habitats to improve habitat conditions, however, could be difficult. Some types of restored habitats may be relatively easy to reverse, such as habitat restored on levees. Setback levees and island elevation restorations, however, would be very difficult and expensive to reverse, and from a practical standpoint, would likely be considered irreversible. Island flooding could be reversed by fixing any breaches and pumping water off of the island. However, as demonstrated at Jones Tract in 2004, this is a very expensive undertaking.

5.1.4 Other Resource Impacts Criteria (#15-#17)

Restoration of aquatic, marsh, and floodplain habitats to create habitat for covered fish species is expected to substantially increase the extent of habitats for other aquatic-, marsh-, and riparian-associated wildlife and native vegetation. Creation of intertidal habitats along levee setbacks and on islands could also potentially increase occurrences of intertidal special-status plant species within the Delta. Depending on the types of farmland removed from production, creation of wetlands may result in net increase or decrease in forage for waterfowl, cranes, and other species. Potential benefit and impact mechanisms of Bundle #18 for other native species are the same as for bundles #19 and #20. The extent of habitat area affected under Bundle #18, however, is expected to be greater and the potential for impacts on species that forage on crops could be greater because the extent of high value cropland foraging habitats that could be affected is substantially greater than in the central and south Delta.

Extensive restoration of habitats in the Delta may also affect, to an unknown degree, native species located outside of the BDCP planning area through enhanced flows, water quality, and food production. Loss of agricultural land could negatively impact wintering waterfowl and cranes. The likelihood for this effect occurring with Bundle #18 is greater than for the other restoration bundles because most of the high value forage crops and crane wintering areas are located in this part of the BDCP planning area.

The actions involving the creation of habitat on existing levees would not have any effects on the human environment. The creation of setback levees involves the moving of a lot of material, so an aggressive program to create them throughout sections of the Delta would have traffic, air quality, noise, cultural resources, water quality, and other impacts on the human environment. In addition, the creation of setback levees would likely cause the loss of some currently productive agricultural land, which would have adverse local and regional socio-economic effects. The flooding of whole islands would remove much more farmland from economic productivity and would therefore have even greater adverse local and regional socio-economic effects.

5.2 BUNDLE #19: RESTORE PHYSICAL HABITAT IN THE CENTRAL DELTA

Bundle 19 includes elements that involve the physical restoration of habitat in the central Delta:

- 19a. Same as 18a
- 19b. Same as 18b
- 19c. Same as 18c

5.2.1 Biological Criteria (#1-#7)

5.2.1.1 Smelt (Delta and longfin)

Restoration of habitat conditions within the central Delta are expected to have the same effects as described for Bundle #18.

5.2.1.2 Sturgeon (green and white)

Restoration of physical habitats in the central Delta with improved levee habitat conditions, levee setbacks and island breaching would provide more desirable habitat (SLC 3) to young sturgeon improving condition and survival. Juvenile sturgeon out-migrate and disperse to their nursery grounds, the Delta, during the summer to early fall. Sturgeon spend one to four years in the fresh waters of the Delta nursery areas before leaving for salt water environments. Therefore, habitat improvements throughout the Delta could have a moderate to high beneficial effect on the population.

Delta restoration that would increase abundance of vegetated shallow water habitat should increase the abundance and diversity of food available to juvenile sturgeon (SLC 4). Access to the flooded island areas may improve overall survival and growth of sturgeon due to greater food quality and quantity, and possibly better cover. Population effect of this bundle on food supply would be expected to be moderate to high.

Restoration of physical habitats in the Delta will increased carbon input via floodplains and vegetation of riparian zones, and would increase Delta food availability (SLC 6?). The effect of this action on this element could be moderate, but the degree is dependent on the area of restoration.

Delta levee breaches could increase species abundance and meet short-term needs of sturgeon. Creation of new or improved riparian zones as levee maintenance is preformed would create similar benefits but to a lesser degree on a longer period (SLC 7).

Beneficial effects of this bundle on sturgeon populations would likely be medium to high if large areas were improved. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

5.2.1.3 Salmonids

The assessment of effects of restoring habitat in the central Delta is the same as described for Bundle #18, except that benefits of restoring habitat would likely be less because fewer salmonids pass through the central Delta.

5.2.1.4 Splittail

The effects of this HRB are similar to those in HRB #18 with few exceptions. Most importantly, the geographic extent is more limited in this element, so the impact on the overall splittail population will be lower than HRB #18. However, it likely would be able to be implemented more quickly due to the lower amount of habitat (SLC 7). Also, because the western Delta (HRB #18) is most likely to contain brackish waters under current configurations, habitat restoration of the central Delta (this HRB) will likely not have as big of an impact on adult splittail as HRB #18 (SLC 3).

5.2.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The restoration of physical habitat in the Central Delta faces the same practical hurdles as those described for Bundle #18. However, because subsidence in the Central Delta tends to be more pronounced than in the North, East, West, or South Delta, the hurdles related to subsidence would be worse under this bundle than under Bundles #18 and 20.

Unit restoration costs for bundle #19 could be somewhat higher than those for bundle #18 because higher rates of subsidence in the Central Delta could require additional expenditure for filling and grading. Total costs would likely be lower than bundle #18 due to the smaller geographic area targeted for restoration actions, though the cost reduction is unlikely to be proportional to the area reduction. As described for Bundle #18, funding feasibility is considered high.

5.2.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

The evaluation of these criteria is the same as described for Bundle #18.

5.2.4 Other Resource Impacts Criteria (#15-#17)

The benefit and impact mechanisms for Bundle #19 are the same as described for Bundle #18. The potential for benefiting waterfowl and other species that forage both in wetland and agricultural habitats, however, is likely greater because lower value forage crops are generally grown in the central Delta. Potential impacts on cranes would potentially be less than under Bundle #19 because fewer cranes currently use these portions of the Delta. Similarly, the mechanisms affecting species outside the Delta would be the same as in Bundle #18, but to a lesser degree, particularly for foraging waterfowl and cranes.

The actions to be undertaken under Bundle #19 would be the same as those under Bundle #18, so the effects on the human environment would be the same. However, because the Central Delta is a smaller geographic area than that encompassed by the North, East, and West Delta, the amount of potential restoration in the Central Delta is assumed to be less, and the magnitude of effects would likely be less under Bundle #19 than under Bundle #18.

5.3 BUNDLE #20: RESTORE PHYSICAL HABITAT IN THE SOUTH DELTA

Bundle 18 includes elements that involve the physical restoration of habitat in the south Delta:

- 20a. Same as 18a
- 20b. Same as 18b
- 20c. Same as 18c

5.3.1 Biological Criteria (#1-#7)

5.3.1.1 Smelt (Delta and longfin)

Restoration of habitat conditions within the central Delta is expected to have similar effects as described for Bundle #18 except that habitat improvements in the south Delta are likely to produce lower benefit to smelt than improvements elsewhere within the estuary.

5.3.1.2 Sturgeon (green and white)

Restoration of physical habitats in the south Delta with improved levee habitat conditions, levee setbacks and island breaching would provide more desirable habitat (SLC 3) to young sturgeon improving condition and survival. Juvenile sturgeon out-migrate and disperse to their nursery grounds, the Delta, during the summer to early fall. Sturgeon spend one to four years in the fresh waters of the Delta nursery areas before leaving for salt water environments. Beneficial population effects on sturgeon could be low to moderate, lower than for other parts of the Delta since juvenile sturgeon enter the Delta from the north.

Restoration of physical habitats in the Delta with improved levee habitat conditions, levee setbacks and island breaching would increase abundance of vegetated shallow water habitat that should increase the abundance and diversity of food available to sturgeon (SLC 4). Access to the flooded island areas may improve overall survival and growth of sturgeon due to greater food quality and quantity, and possibly better cover. Population effect of this bundle on food supply for sturgeon would be expected to be moderate to low, lower than for other parts of the Delta since juvenile sturgeon enter the Delta from the north.

Delta restoration will increased carbon input via floodplains and vegetation of riparian zones, and would increase Delta food availability (SLC 6?). The effect of this action on this element could be moderate, but the degree is dependent on the area of restoration.

Delta levee breaches could increase species abundance and meet short-term needs of sturgeon. Creation of new or improved riparian zones as levee maintenance is preformed would create similar benefits but to a lesser degree on a longer period (SLC 7).

Beneficial effects of this bundle on sturgeon populations would likely be medium low if large areas were improved. Based on the limitation of information, the certainty of the assessment of this bundle is considered moderate to low.

5.3.1.3 Salmonids

The assessment of effects of restoring habitat in the south Delta is the same as described for Bundle #18, except that restoring habitat primarily benefit the SJR population of fall-run Chinook salmon.

5.3.1.4 Splittail

The effects of this HRB are similar to those in HRB #18 with few exceptions. Most importantly, the geographic extent is more limited in this element, so the impact on the splittail population will be lower than HRB #18. However, the south Delta has been identified as an area with little juvenile suitable rearing habitat, so the effect will be larger than HRB #19. South Delta restoration would be able to be implemented more quickly than HRB #19 but at about the same time as HRB #19 due to the geographic coverage (SLC 7). True restoration will be difficult without concurrent changes to water operations and/or improvements to hydrological conditions. Also, because the western Delta (HRB #18) is most likely to contain brackish waters under current configurations, habitat restoration of the south Delta (this HRB) will likely not have as big of an impact on adult splittail as HRB #18 (SLC 3).

5.3.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The restoration of physical habitat in the South Delta faces the same practical hurdles as those described for Bundle #18. Unit restoration costs would also be similar to those for bundle #18. Total costs would be lower due to the smaller geographic area targeted for restoration actions. As described for Bundle #18, funding feasibility is considered high.

5.3.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

The evaluation of these criteria is the same as described for Bundle #18.

5.3.4 Other Resource Impacts Criteria (#15-#17)

The evaluation for Bundle #20 is the same as described for Bundle 19.

The actions to be undertaken under Bundle #20 would be the same as those under Bundle #18, so the effects on the human environment would be the same. However, because the South Delta is a smaller geographic area than that encompassed by the North, East, and West Delta, the amount of potential restoration in the Central Delta is assumed to be less, and the magnitude of effects would likely be less under Bundle #20 than under Bundle #18.

5.4 BUNDLE #21: RESTORE SUISUN MARSH HABITAT

Bundle 21 includes elements involving the restoration of Suisun Marsh habitats:

- 21a. Breach dikes in Suisun Marsh to reestablish tidal exchange and create tributary channels necessary to create high quality intertidal marsh and aquatic habitats.
- 21b. Modify operations of salinity control structures in Suisun Marsh to improve flow-related habitat conditions for covered fish in Suisun Marsh.

5.4.1 Biological Criteria (#1-#7)

5.4.1.1 Smelt (Delta and longfin)

Habitat improvements in Suisun Marsh would benefit smelt as described for the Delta. Habitat improvements for smelt within Suisun Marsh would have a moderately high value.

5.4.1.2 Sturgeon (green and white)

Improvements to Suisun Marsh with the creation of intertidal flooded plains and management to improve water flows would significantly improve water quality and flow conditions (SLC 2) available at those sites for sturgeon. Natural flushing in those areas buffers temperature spikes and DO sags. Cooler waters with higher oxygen levels would lower stress in sturgeon and help maintain their health. Juvenile sturgeon's nursery grounds are in the Delta and few are thought to reside in Suisun Marsh. The densities of other sturgeon life stages in the marsh are believed to be low. Therefore, the water quality effect of this bundle on the sturgeon population is expected to be low.

Suisun Marsh habitat improvements (SLC 3) with improved access would slightly improve the overall availability of desirable habitat for sturgeon. Sturgeon densities are thought to be low in the marsh. Therefore, the habitat improvements in the marsh would have a low beneficial effect on the population.

Modifications to Suisun Marsh with increased abundance of vegetated shallow water habitat will increase the abundance of food availability (SLC 4) in and down stream of the marsh to San Pablo Bay. Restoration that improves food production (carbon input) also contributes to the richness of the bay where adult sturgeon reside. Improved access to the tidal plains may improve overall survival and growth of some sturgeon due to greater food quality and quantity, but due to estimated low density the likely effect on population abundance in most years will be moderately low.

Levee breaching with habitat creation and re-operation of the salinity control gates in Suisun Marsh could produce a small increase in species abundance on a short time frame (SLC 7).

Due to low sturgeon density in the geographic area of this bundle, the population effect on sturgeon are thought to be low. Based on limited information, the certainty of the assessment of this bundle is considered moderate to low.

5.4.1.3 Salmonids

Restoration of intertidal aquatic and marsh habitats in Suisun Marsh likely have low benefits to the salmonids at the population level under existing habitat conditions upstream of the Delta. The benefits of restoring Suisun Marsh habitat for salmonids, however, would likely increase if upstream spawning and rearing habitats were restored and the number of smolts moving out of the Delta were increased. Mortality from non-native predators could be reduced as a result of creating habitat conditions that disfavor predators and provide cover for smolts (SLC 1 and SLC 5). Restoration of extensive habitat areas would be expected to increase food production by increasing residence time of water. Increased food production could increase the period that smolts reside in Suisun Marsh and Bay before migrating downstream, thus improving the condition of fish moving to SF Bay and possibly increasing survival (SLC 3 and SLC 4). With the exception of control of invasive non-native plants and dike maintenance, restored habitats would be expected to be supported by ecological processes, assuming that habitats are restored to elevations that provide the surface and subsurface hydrologic conditions necessary to support desired vegetation and other habitat elements (e.g., water depth, water velocity) (SLC 6). Full implementation of this Bundle would likely take less time to implement than Bundles 18-20 because restoration plans for Suisun Marsh are currently in development and a process for securing restoration lands are in place (SLC 7).

5.4.1.4 Splittail

If we assume that restoring Suisun Marsh would reduce toxics in the marsh from past agricultural practices, commercial effluents, and other sources, this HRB would likely contribute to moderate reductions in mortality of non-reproductive adults and rearing juveniles dwelling in Suisun Marsh (SLC 1). Exposure to toxics was identified as a major stressor in Technical Workgroup meetings. This restoration may reduce non-native abundance because conditions would mimic natural conditions under which natives evolved and to which natives are adapted, although this effect is minimal on overall splittail populations. In all, the restoration of Suisun may provide moderate reductions in overall abundance. The certainty of the effects of restoration on splittail mortality is relatively low.

Water quality and flow conditions for splittail would likely improve if there is more current in Suisun Marsh as a result of restoration (SLC 2). However, because splittail are tolerant of a wide range of environmental conditions, this effect will be moderate.

Restoring Suisun Marsh will likely have large positive impacts in terms of providing habitat for splittail (SLC 3). Conditions found in Suisun are thought to be preferred by adults and for juvenile rearing (shallow, brackish, tidally influenced, turbid, and soft-bottomed). Along with floodplain improvement, creation, and restoration bundles (#17-20), this bundle should have the greatest impact on the splittail population.

Restoration of Suisun Marsh will likely change the prey sources available to splittail (SLC 4). Although highly speculative, the restoration could make environmental conditions better for native prey species and/or worse for non-natives. This may increase the quality of prey if non-natives were lower quality than natives. If anything, this would provide splittail with native species to which they evolved.

Although speculative, it is thought that restoration of Suisun Marsh would improve environmental conditions for natives that may have evolved there and/or worsen conditions for non-natives (SLC 5).

Restoration of Suisun Marsh will likely improve ecosystem processes for splittail because there would be more habitat available and conditions that are similar to historic conditions (SLC 6).

Because this project is already in the works, it will likely take less time to implement than starting from scratch as would be done for #18-20 (SLC 7).

5.4.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The Suisun Marsh Charter Group is developing a habitat restoration plan for Suisun Marsh. Habitat restoration would include restoration of tidal marsh as well as non-tidal habitats for waterfowl and other species. The feasibility of various actions is being evaluated through that planning process. Because much of Suisun Marsh is privately owned, the ability to breach dikes to create tidal wetlands will require the willing participation of these landowners.

The cost of restoring Suisun Marsh intertidal habitats will depend on the extent restoration, the extent to which restoration requires acquisition of private land, environmental permitting requirements, as well as other factors. The Ecosystem Restoration Program Plan (ERPP) of CALFED identified specific recovery measures to restore tidal action to 5,000 to 7,000 acres in the Suisun Bay within seven years of its initiation (ERPP 1999). The Baylands Ecosystem Habitat Goals recommended restoration of tidal marsh in the Suisun subregion, with a specific recommendation of more than doubling the area of tidal marsh to between 30,000 and 35,000 acres (Goals Project 1999).

A multi-phase project to restore 500 acres of managed wetlands to tidal marsh was proposed by DWR, DFG, USBR, USFWS, and SRCD in 2002.[18] This project proposed to (1) acquire parcel(s) in northern or western Suisun that are contiguous with or in close proximity to existing tidal wetlands, (2) restore these parcel(s) to a self-sustaining tidal marsh that includes the full elevational range from slough channel to low marsh, middle marsh, high marsh, transitional zones, and upland areas, and (3) assist in the recovery of at-risk species. The restoration project was expected to cost $3.7 million (updated to 2006 dollars), broken down as follows: (1) land acquisition ($1.1 million); develop restoration plan ($0.5 million); environmental compliance, engineering, monitoring plan ($0.8 million); restoration activities ($1.1 million); post project monitoring/performance evaluations ($0.2 million). The average cost per restored acre is $7,400.

Assuming an average restoration cost of $7,400/acre, restoring 5,000 to 7,000 acre in Suisun Bay as recommended by the ERPP would cost between $37 million and $52 million. Restoring 15,000 to 17,500 acres as recommended by the Goals Project would cost between and $111 and $130 million.

The capital costs associated with this bundle would be moderate (tens to hundreds of millions of dollars). As described for Bundle #18, funding feasibility is considered high.

5.4.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Potential effects of sea level rise on restored Suisun Marsh habitats are the same as described for Bundle #18. Because of diked lands are not as nearly subsided as Delta islands, potential loss of habitats as a result of dike failures is expected to be less than for habitats restored on Delta islands.

Restoration of intertidal aquatic and marsh habitats and hydrologic and salinity regimes in Suisun Marsh are expected provide the physical and water quality conditions required by covered species. With the exception of control of invasive non-native plants and dike maintenance, the need for ongoing human interventions to maintain habitats is expected to be

[18] http://calwater.ca.gov/Programs/EcosystemRestoration/2002_Final_Proposals/17_compilation.pdf

minimal, assuming that habitats are restored to elevations that provide the surface and subsurface hydrologic conditions necessary to support desired vegetation and other habitat elements (e.g., water depth, water velocity). If intertidal habitats are restored as "managed cells", then dikes will need to be periodically maintained to prevent dike failures. The adaptability of restoring habitats is the same as described for Bundle #18. Restored habitats would be more easily reversed than restored Delta habitats because lands are not as subsided.

5.4.4 Other Resource Impacts Criteria (#15-#17)

Restoration in Suisun Marsh is not expected to measurably affect other native species within the Delta. However, it would significantly benefit native species outside of the BDCP planning area that use intertidal aquatic and marsh habitats. Restoration of nontidal marsh and agricultural land to intertidal habitat would displace native species that do not also use intertidal habitats. Potential effects on waterfowl would be expected to be similar to those described for Bundle #18.

The flooding of whole islands in Suisun Marsh would remove the economic uses from islands currently under agricultural production or serving as duck clubs, which would have adverse local and regional socio-economic effects.

5.5 BUNDLE #22: RESTORE AND PROVIDE ACCESS TO SPAWNING AND REARING HABITAT UPSTREAM OF DELTA

Bundle 22 includes elements that involve the enhancement and restoration of spawning and rearing habitat in areas upstream of the Delta:

- 22a. Restoration of salmonid spawning habitats, including gravel augmentations, providing for channel meander to enhance inputs of spawning gravels, installing barriers to separate Chinook runs
- 22b. Expansion of river floodplain habitat including creation and expansion of new floodways to restore rearing habitat and splittail spawning habitat
- 22c. Removal of bank protection to reestablish floodplain processes that support creation and maintenance of spawning and rearing habitat
- 22d. Restoration of riparian habitat including shaded riverine aquatic cover
- 22e. Improving passage and access to upstream habitats, including removing, modifying, or bypassing barriers

5.5.1 Biological Criteria (#1-#7)

5.5.1.1 Smelt (Delta and longfin)

This bundle is expected to have negligible to no effect on smelt populations.

5.5.1.2 Sturgeon (green and white)

Stream bed restoration and opening up upstream habitats would moderately improve the condition and survival of all life stages of sturgeon upstream of the Delta by increasing shading which could improve water temperatures and through dissipation of flood flow energy lower flow velocities (SLC 2). These actions could provide the slow flows that juvenile sturgeon seek during the summer month as they move down stream to the Delta. The greatest benefits of this bundle would be if these restorations were spread out over a long reach. Population level effects are expected to be low to medium.

Upstream restoration that provides coarse, stable substrate would be beneficial to sturgeon spawning success (SLC 3). Barrier removals or modifications and floodplain expansion could improve the condition and numbers of adult sturgeon reaching the spawning grounds. Adult sturgeon up-migrate for spawning starting with white sturgeon in February to June with green sturgeon. The expansion of range or improvement of numbers of sturgeon in separate drainages is essential to population resilience. Population level effects should be medium.

Habitat improvements of bypasses and floodways with channel (drainage) reconstruction, riparian zone expansion and improved access would moderately improve overall food supply (SLC 4) on the floodplains, streams and downstream in the Delta. Floodplains are rich food producers. Studies in the Yolo Bypass have shown that juvenile fish passing through the bypass are larger and have a higher condition factor than fish passing down the river corridor. This should result in a higher survival ratio of out migrants and would also, to a lesser degree, benefit sturgeon in their Delta nursery grounds. Increased carbon input via floodplains would increase food availability to the Delta (SLC 6?). The benefits of this bundle on sturgeon food quantity and quality will fluctuate and are dependent on hydrologic conditions. The likely effect on the sturgeon population in most years will be moderate.

Upstream removal of bank protections, improvements in fish passage, and gravel augmentations could increase species abundance and meet short-term needs of sturgeon. Creation of new or improved riparian zones and the expansion of the river floodplain would create similar benefits on a longer period (SLC 7).

Beneficial effects of this bundle on sturgeon populations would likely be medium to high if large areas were improved. Based on the available information, the certainty of the assessment of this bundle is considered moderate to high.

5.5.1.3 Salmonids

Restoration of upstream salmonid spawning and rearing habitat and providing passage to existing, but inaccessible, habitat is expected to provide maximum benefits to salmonids at the population level relative to all other evaluated bundles. Full implementation of this bundle would create habitat conditions that would provide the potential for substantial increases in production and survival of fry and smolts. Mortality from non-native predators could be reduced as a result of reestablishing connectivity between floodplains and river and stream channels, thus creating habitat conditions that disfavor predators and provide cover for fry and smolts (SLC 1 and SLC 5). Restoration of extensive floodplain habitats would be expected to increase food production and provide for the rapid growth of fry and smolts (SLC 3 and SLC 4). With the exception of levee maintenance, structures that maintain habitat conditions (e.g., passage facilities), and gravel augmentations, restored habitats would be expected to be supported by ecological processes, assuming that habitats are restored to elevations that provide the hydrologic conditions necessary to support spawning and rearing habitat (e.g., water depth, water velocity) (SLC 6). This bundle would likely take longer than Bundle #21 to implement because of the time likely required to secure the extent of lands necessary for full implementation and to resolve uncertainties associated with providing fish passage upstream of existing dams. Full implementation of this Bundle could take less time to implement than PBs 18-20 because the expected outcomes of this bundle are more certain than for restorations in the Delta, thus requiring less time to test the efficacy of restoration concepts (SLC 7).

5.5.1.4 Splittail

Although much of this bundle will likely do little to improve splittail populations, the expansion of floodplain habitat will have similar effects to Bundle #17, although more extensively here. It would likely be implemented in a timeframe similar to the other HRBs, but is dependent on the extent of restoration at a site and the geographic extent of the restoration.

5.5.2 Planning Criteria (#8-#10)

This bundle is not expected to affect the ability to achieve the goals and purposes of the covered activities. The enhancement of spawning gravel in rivers has been undertaken for many years. The only significant hurdle to expanding this activity is the availability of suitable gravel. The installation of barriers to separate Chinook salmon runs would not have any unusual feasibility constraints. The expansion of river floodplain habitats, including the creation or expansion of floodways would require the acquisition of land or easements from willing sellers and would likely take farmland out of production, which would have local and regional socioeconomic effects. In addition, adjacent and downstream landowners would need to be satisfied that these activities did not increase their flood risk. The removal of bank protection and the creation of riparian habitat along levees would face hurdles related to land ownership, conflict with the Corps policy regarding vegetation on levees, and ensuring that the project would not increase flood risks for adjacent or downstream landowners. The removal of barriers to fish passage will require the cooperation of landowners or water districts. If the barrier in question happens to be a dam serving an economic purpose, there is likely to be opposition from the owners and socioeconomic effects related to the removal of the dam.

Costs for bundle #22 will vary by type, extent, and location of physical habitat restoration projects. The CALFED Draft Finance Options Report evaluated costs for ERP projects funded by grants between 1997 and 2001. This analysis estimated cost ranges for Central Valley (mainly Sacramento and San Joaquin Rivers) habitat acquisition, terrestrial/wetland habitat restoration, instream habitat restoration, and fish passage as shown in the following table.

Range	Land Acquisition ($/Ac)	Terrestrial Restoration ($/Ac)	Instream Restoration ($/Mi)	Fish Passage ($/Project)
Low	$2,700	$100	$660,000	$3,000,000
High	$3,500	$1,400	$1,400,000	$3,000,000

These unit costs could be coupled with habitat acquisition and restoration levels as they become available to generate preliminary cost ranges for alternative levels of restoration.

As an example of potential cost magnitude, we note that according to the CALFED Finance Options Report the ROD identified about 185 miles of above-Delta instream habitat and about 10,000 acres of Central Valley riverine habitat for restoration. Additionally, it identified 26 above-Delta fish passage projects. Using the above unit cost ranges for a preliminary cost range to restore this level of above-Delta spawning and rearing habitat would be on the order of $230 to $390 million.

The capital costs associated with this bundle would be moderate (hundreds of millions of dollars), some of the actions would be irreversible, and the actions could be funded incrementally. As described for Bundle #18, funding feasibility is considered high.

5.5.3 Flexibility/Durability/Sustainability Criteria (#11-#14)

Effects of sea level rise and seismic events are expected to be minimal relative to habitats restored in the Delta. Climate change could, however, alter the hydrology sufficiently to change the frequency, timing, and duration that floodplains habitats are inundated.

With the exception of gravel augmentations, actions under this bundle (e.g., creating flood bypasses, removing barriers to passage, removing bank protection, and providing for channel meander) will reestablish ecosystem processes that support channel and floodplain habitats. Implementation of these measures is expected to require minimal ongoing human intervention to maintain restored habitat conditions. Measures that include structures to provide species benefits (e.g., weirs) will require periodic ongoing maintenance to maintain their functionality. The adaptability of habitat restorations is the same as described for Bundle #18. Restoration activities could involve very simple activities such as dredging or larger, more involved activities such as removing dams or constructing fish ladders and screens. The smaller activities would be relatively easily reversible. The larger activities such as dam removal would be relatively irreversible and the construction of fish screens and fish ladders would be moderately reversible.

5.5.4 Other Resource Impacts Criteria (#15-#17)

Upstream habitat restoration for covered species is not expected to affect other native species within the Delta. It would, however, improve habitat conditions for other native aquatic species where implemented. Restoration of riparian vegetation along channels to provide SRA for fish would also create habitat for riparian-associated birds and restoration of floodplain habitats and overbank flooding would also be expected to improve habitat conditions for resident and migrant waterfowl, shorebirds, wading birds, and other water birds of the Central Valley.

Some of the activities in Bundle #22 would involve construction and perhaps the conversion of some agricultural lands, but they would be on a local scale and occur over relatively short periods of time. Compared to the other Analysis of Physical Restoration Bundles, the effects of Bundle #22 would be low.